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OF THE 11TH INTERNATIONAL CONFERENCE
ON INTELLIGENT ENVIRONMENTS

Ambient Intelligence and Smart Environments

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Workshop Proceedings of the 11th International Conference on Intelligent Environments

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Introduction to the Proceedings of the Workshops of IE'15

Prague – Czech Republic 13–14 July

Socrates once said "I know that I am intelligent, because I know that I know nothing". I believe that being aware of your strengths and weaknesses, what motivates you and your decision making, how you learn from your mistakes and how that self-awareness changes your behavior is what makes human beings intelligent. Today, we have come to an era where many of these human traits are being embedded into our surroundings to create intelligent environments that address our needs and support us in our daily lives. But what is it that makes our environments intelligent? Does our environment deserve it to be called intelligent whenever it can deceive us into believing it is human, like in Alan Turing's test? Or do we expect something else beyond intelligent environments mimicking human behavior? It makes you want to think about how technology is intertwined with society and how we will evolve in the future.

With emerging trends like the Internet of Things, we are deploying and connecting sensors and actuators everywhere to gain information and solve problems. And people expect such systems to be trustworthy, dependable and reliable under all circumstances. However, developing intelligent environments with some common sense seems to be a lot more complicated, and we are probably more than a decade away from sophisticated networked systems exhibiting human-like thoughts and intelligent behavior. But with the growing digital divide, an intelligent environment that passes the Turing Test is not that unimaginable. Therefore, the goal of intelligent environments is not to strive towards the technological singularity, but rather to strengthen both human beings and the technology that surrounds us such that they both will learn to do better and continue to successfully fulfill many achievements. For us, researchers, educators and practitioners, there are long and interesting roads ahead.

As part of this journey, the 11th International Conference on Intelligent Environments focuses on the development of advanced intelligent environments, as well as newly emerging and rapidly evolving topics. This year, we are pleased to include in this volume the proceedings of the following workshops and symposia that cover exactly the above challenges, i.e. reliable intelligent environments – from the home to the workplace – and how we can use them for pedagogical purposes:

- *4th International Workshop on Smart Offices and Other Workplaces (SOOW'15)*
- *4th International Workshop on the Reliability of Intelligent Environments (WoRIE'15)*
- *Symposium on Future Intelligent Educational Environments and Learning 2015 (SOFIEEe'15)*
- *1st immersive Learning Research Network Conference (iLRN'15)*

As can be witnessed from the above list, the workshops and symposia organized in conjunction with the main conference provide a forum for researchers, scientists and engineers to engage in many interesting and thought provoking discussions that will nurture further research in these key areas of Intelligent Environments. The proceedings compile research and insights into the latest developments of active researchers in these fields. We sincerely hope that you as a reader will enjoy the content of these proceedings, and find them an inspiration for your own work.

As a final note, the editor of this volume would like to take the opportunity to thank everybody who made these proceedings possible. First of all, I would like to express my gratitude to all the authors and researchers that pushed the boundaries of science and created new advances and insights in their field of work. Second, I am also grateful to the organizing committees of these workshops. Without your efforts these events would not have been possible. Thanks also to their program committees that contributed to the reviews of the papers. Finally, I would like to thank the conference organizers and local staff that worked relentlessly behind the scenes to provide a supportive environment and to make these events a success.

I am looking forward to seeing you all in Prague and enjoying the unique character and enthusiasm of the IE workshops.

May 2015

Davy Preuveneers, University of Leuven, Belgium

Workshops Chair of IE'15

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Editors

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Workshop Proceedings of the 11th International Conference on Intelligent Environments
D. Preuveneers (Ed.)

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Introduction to the Proceedings of SOOW'15

Ambient intelligence approaches and technologies are more and more matured to be able of creating a smart environment that is intelligently helpful to users surrounded by such an environment. Besides a number of well-known applications of this concept in various areas, like smart home environment, or smart support to elderly or handicapped people, it is also very suitable for intelligent workplaces development. Integrating context-aware devices and assistive software solutions into the workplace brings increase in productivity and improvement in work experience while optimizing resource consumption. The concept of a smart office builds on a home automation solution but extends it with the need to align to business scenarios. In home automation the workplace can be customized mainly in environmental conditions such as temperature, humidity, light intensity, noise and also in physical disposition of furniture, desktop arrangements etc. The business scenario requires the solution to ensure effectiveness in everyday tasks and thus communicate with project management, database and information systems. An intelligent workplace can be also helpful in managing knowledge which can be usefully needed by the users working in the workplace. Such knowledge can be used not only for solving various problems requiring expert knowledge to be properly solved, but also for learning at the workplace when creating decisions or looking for solutions of difficult tasks.

The 4th International Workshop on Smart Offices and Other Workplaces (SOOW'15) aims to unite academics and practitioners with their research in various aspects related to the concept of smart office and open platform for a vivid scientific discussion. This year SOOW will bring aspects ranging from large-scale view of intelligent environment to an aid for decision makers and further to intelligent system for message organization. The large-scale view explores ideas how environmentally oriented wireless sensor networks used in "large-scale" throughout the open natural environment could be enhanced using some recent ambient intelligence approaches in order to be beneficial in preventing primarily environmentally related problems. The decision making aid will employ intelligent agents to analyse and represent strategies of decision makers in a group decision making setting. There is also a novel approach to organization of messages that offers easier searching of large quantity of disparate emails or phone calls and sharing them in a unified form among many users.

During the recent years, the workshop Smart Office and Other Workplaces was organized bi-annually as a satellite event along the international Conference on Intelligence Environments. The previous workshops were organized in remarkable cities such as Barcelona, Nottingham and Athens. This year SOOW is held in Prague, Czech Republic. Prague as the city with an extensive historic centre which has been included in the UNESCO list of World Heritage Sites is also the heart of Czech science and provides welcoming atmosphere for any scientific event. We hope that 4th International Workshop on Smart Offices and Other Workplaces (SOOW'15) will be enjoyed by all its participants.

Peter Mikulecký, Goreti Marreiros, and Pavel Čech
Co-chairs SOOW'15

Workshop Proceedings of the 11th International Conference on Intelligent Environments
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Dealing with Agents' Behaviour in the Decision-Making Process

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Abstract. Gathering a group of managers or executives (decision-makers) in a same place and at a same time is not an easy task. In fact, the decision-makers' schedule is so tight that it becomes necessary to develop tools that will aid in the communication and in the decision-making process. The intelligent systems (IS) can be the solution to overcome these necessities. In literature, there have been appearing more and more IS that make use of multi agent systems (MAS) in order to represent real decision-makers in this type of systems. In our work we address the problem of how agents should behave during the decision-making process and what strategies they can follow to represent the interests of the decision-maker. We intend to define valid behaviours for agents in group decision-making context and to relate the theoretical behaviours definition with usual attitudes and acts that are relevant for this context. We define two dimensions and relate them with two facets based on the Five Factor Model. Then we propose the behaviours classification according three different levels (low, moderate and high) for each one of the dimensions. We use the value of the personality trait correspondent to each facet in order to classify our behaviours in the scale.

Keywords. Intelligent Systems, Ubiquitous Group Decision Support Systems, Multi-Agent Systems, Behaviours, Five Factor Model

1. Introduction

The number of studies related to Ambient Intelligence (AmI) has been increasing exponentially over the last decade. AmI can be considered as a relationship between several areas of computer science such as: Artificial Intelligence, Human Computer Interaction, Networks, Sensors and Pervasive Ubiquitous Computing [1; 2]. In order to coordinate AmI, specific systems known as Intelligent Systems (IS) are used [3]. These "intelligent" environments and systems, among other things, can: be pro-active, anticipate scenarios and act autonomously [4].

A recognizable application of intelligent environments is smart offices. In fact, smart offices are seen as the new trend of the traditional offices and decisions rooms [4]. A smart office is nothing more than an intelligent environment that aims to support the Decision-making process. Usually these types of environments are composed of physical components (e.g. sensors, controllers and smart devices) and software (e.g. intelligent agents). The software makes use of the information collected by its physical

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components to reason about the environment and trigger actions in order to change its state [5].

It has become more of a common feature for smart offices to be prepared to make the environment more intelligent and also to create an ubiquitous/pervasive computing platform, i.e. there is the necessity to collect and deal with both all the possible information about the environment as well as with the fact that not every decision-maker will be present at the same place [6]. Many of the intelligent systems that have been proposed for this type of environment include intelligent agents that, among other things, will represent real decision-makers [7-9]. In order to make this representation more intelligent, there have been suggested new strategies, that for example, can identify emotions through the use of sensors, analyse profiles, define personality models, etc. [10-12]. Most models that are used to define personality, strategies or behaviours of the agents, are adapted from scientific literature which is not entirely related to the area of computer science [13; 14].

Many approaches have been suggested in the literature which define/model agents with certain characteristics that differentiate them from each other and as result permit them to operate differently [8; 9; 15-18]. Specifically in the group decision-making context, some behaviour models have been used (conflict style, strategies or personality models) which intend to differentiate the agents according to certain interests. However, there is not one specific definition to really describe how each one of the behaviours should act in group decision-making context. Some appointments that can be used are just not enough, and in the case where the decision-makers perform the modelling of their agent by selecting one behaviour from a list of possible behaviours, it is not possible to know if the agent will act according to the decision-maker's expectations.

In this paper we purpose the inclusion of what we consider the most important dimensions to define agents' behaviours that should be considered in the group decision-making context. We present the adaption of the conflict styles identified by Rahim and Magner [19] to the group decision-making context and we propose 2 new dimensions (plus the adaptation of the 2 dimensions that were identified by Rahim and Magner [19]) to define and differentiate them. In order to be able to classify the different behaviours to each one of the dimensions we propose a correlation between the dimensions and some facets based on Five Factor Model [13]. We use the syntax used by Rahim and Magner (Low, Moderate and High) to classify the behaviour types.

The rest of the paper is organized as follows: in the next section is presented the literature review. Section 3 presents our methods, where we: identify the facets that are relevant to our context; propose 2 new dimensions and how we correlate them with the different behaviour types and present the different levels (low, moderate and high) for each one of the dimensions considering the behaviour types. Finally, some conclusions are taken in section 4, along with the work to be done hereafter.

2. Literature Review

The way different behaviour types can be adapted for an agent to use for a group decision-making context is closely related to how a person behaves in real life and also related to specific traits of personality of each individual. Therefore, it is important to understand which factors are responsible to affect the personality of an individual and how the personality can enhance one specific behaviour type in a situation and a different behaviour type in another.

The first relevant study in this area was made by Jung [20], in 1921 when he specified a model to study different psychological personality types based on four types of consciousness or functions (sensation, intuition, thinking, feeling):

- Sensation – How a person perceives a stimulus through the use of sense organs (smell, taste, touch, hearing, sight);
- Intuition – How a person is able to acquire knowledge without inferring or reasoning;
- Thinking – How a person arrange thought and ideas, and how a person makes sense of the world around him or her;
- Feeling – How a person experiences emotions.

Both thinking and feeling functions are related with one individuals rational side the same way both sensation and intuition functions make part of the irrational side of the individual. These functions can in turn be combined with two types of attitudes (extraversion and introversion) and that way identify eight primary psychological types (Extraverted sensation, introverted sensation, extraverted intuition, introverted intuition, extraverted thinking, introverted thinking, extraverted feeling and introverted feeling).

Following Jung's studies, there have been suggested and developed so many other models applied to several areas of psychology and sociology such as leadership [21], social conflict, which allows us to see the impact that Jung's contributions have had in modern psychology and sociology. With regard to social conflict, our area of study centers in conflict management which has always been an important area of decision-making, since it is very rare to find situations in group discussion where conflict is not present.

In 1975, Kilmann and Thomas [22], based on Jung's studies and a conflict-handling mode proposed by Blake and Mouton [23], suggested a model for interpersonal conflict-handling behaviour, defining five modes: competing, collaborating, compromising, avoiding and accommodating, according to two dimensions: assertiveness and cooperativeness.

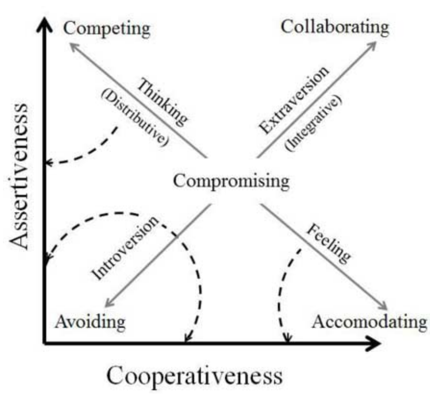

Figure 1. Thomas and Kilmann's model for interpersonal conflict-handling behavior, adapted from [22].

As seen in Figure 1, both assertiveness and cooperativeness dimensions are related to integrative and distributive dimensions which were discussed by Walton and McKersie [24] in 1965. Integrative dimensions refer to the overall satisfaction of the group involved in the discussion while distributive dimension refers to the individual satisfaction within the group. It is possible to see that the thinking-feeling dimension maps onto the distributive dimension while the introversion-extraversion dimension maps onto the integrative dimension. It is easy to understand this association by looking at competitors as the ones who seek the highest individual satisfaction, collaborators as the ones who prefer the highest satisfaction of the entire group. On the other hand avoiders do not worry about group satisfaction and accommodators do not worry about individual satisfaction. They also concluded that the thinking-feeling dimension did not move towards the integrative dimension, and also that the introversion-extraversion did not move towards the distributive dimension.

In 1992, Costa and MacCrae [25] proposed a set thirty traits extending the five-factor model of personality (OCEAN model) which included six facets for each of the factors. These traits were used in a study made by Howard and Howard [13] in order to help them separate different kinds of behaviour styles and identify corresponding themes. A theme is defined as "a trait which is attributable to the combined effect of two or more separate traits". Those styles and themes are based on common sense and general research, and can be inferred such as the conflict styles that were proposed, (Negotiator, Aggressor, Submissive and Avoider), however it is also important to referrer other relevant styles that were suggested such as the Decision and Learning styles. Decision style includes the Autocratic, Bureaucratic, Diplomat and Consensus themes while Learning style includes the Classroom, Tutorial, Correspondence and Independent themes.

In 1995, Rahim and Magner [19] created a meta-model of styles for handling interpersonal conflict based on two dimensions: concern for self and concern for the other. This model was created in order to validate 5 subscales of the Rahim and Magner's Organizational Conflict Inventory (ROCI-II) which measure 5 styles of handling interpersonal conflict.

The styles defined by Rahim and Magner [19] are presented in Figure 2 and have been adapted to our problem. Rahim and Magner [19] reckons the existence of 5 types of conflict styles: integrating, obliging, dominating, avoiding e compromising. In his work, they suggested these styles in particular to describe different ways of behave in conflict situations. They define their styles according to the level of concern a person has for reaching its own goal and reaching other people's objectives.

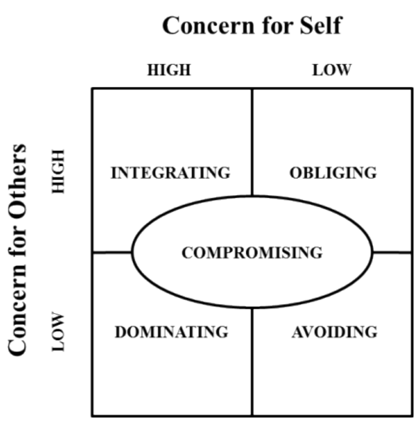

Figure 2. Conflict Style, adapted from [19].

Rahim and Magner's model relates to the themes identified by Howard and Howard [13] to a certain extent. The Aggressor theme resembles the Dominating style; the Negotiator theme resembles the Integrating style; the Avoiding theme resembles the Avoider style; and the Submissive theme resembles the Obliging style. The main difference is the existence of the Compromising style in Rahim and Magner's model which does not relate to a specific theme. In theory the Compromising style is an intermediate state between the other styles that were identified.

3. Methods

Before we introduce our proposal, there are a few, yet relevant questions that must be addressed in order to understand our point of view and how that will also has impact in the way we will develop it.

As mentioned before we have considered 5 main behaviour types, following Rahim and Magner's studies: Integrating, Dominating, Compromising, Obliging, Avoiding. These styles will be available during the agent's configuration process and will be responsible for instructing the agent on how to behave during the decision-making process in the system.

What is important to know is:

- What differentiates each behaviour type? It is obvious that each behaviour should be different, otherwise having agents with different behaviours and acting the same way in the system would just be completely useless;
- How will an agent behave after the configuration? Defining what the agent will do is the next step to take into account because even if we can distinguish one agent's behaviour from another, if we cannot transform that into actions to be performed in the system it will also be useless for our goal;
- How will the decision-making process work? Now that we have our agents well defined and differentiated we're ready to use them in a decision-making context, however it is necessary to know how the system will perform;
- How will the agents interact with each other? What information can be exchanged? How will that information be exchanged? If agents do not interact with each other and exchange information, the decision-making process ends with no decision at all. It is important to define how the agents will communicate with each other.

Considering Costa and MacCrae [25] 30 facets, we have identified those that are relevant and make sense in our context. From all the existing facets, we consider that the most relevant facets are: activity, altruism and compliance (Table 1).

Table 1. Facets that define specific behaviour types for decision-making context.

Facet	Low	Moderate	High
Activity	Leisurely	Average Pace	Vigorous
Altruism	Uninvolved	Willing to Help Others	Eager to Help
Compliance	Aggressive	Approachable	Defers

The activity facet is considered because it allows to differentiate participants that are more or less active during the discussion. It is easy to identify, during a group decision-making process, participants that play a more active role by openly inquiring other participants or making statements, and there are also participants that are less active and usually only participate when asked to share their thoughts or opinions, without having the will to take initiative and try to solve things on their own. The altruism facet is important because it reveals the concern that one participant might have for other participants and their opinions. This will show to what extent the participant will be willing to understand other individual's point of view on the same matter or why they defend one opinion instead of another. Compliance is also a necessary facet in our context because it differentiates the level that each agent will have towards accepting or refusing to change opinion during the discussion. If all agents refuse to change their opinion it will be very difficult to reach an agreement. If all agents are willing to accept new opinions it will be easier to reach a consensus.

Just by looking at these facets' definition we begin to understand that it will be very important for a group decision-making context to have a mixture of all the possible levels for each facet (low, medium, high) spread through the different behaviour types, according to each behaviour's definition and that some of those behaviours may also share the same levels for one or more facets. However that does not mean that in practice, agents will behave exactly the same way. They might share some common characteristics but in the end, their behaviour will be distinguished by not what they do the same way, but by what they do in different ways.

For our work we considered Rahim and Magner's dimensions for concern for self and concern for others:

- Concern for others – This dimension is related to the altruism level of each agent and how much the agent will worry about other participant's opinions. This means that an agent with a high concern for others will ask more questions to try understanding other participant's point of view compared with an agent with low concern for others;
- Concern for self – This dimension is also related to the altruism level of each agent and the value given by an agent to its own opinion and how he will express his own opinion in the presence of others. An agent with a high concern for self is going to make more statements to justify and defend his opinion compared with an agent with low concern for self.

Looking at the definition of each behaviour type it becomes easy to understand how the dimensions will affect each behaviour type based our own definition of the group decision-making context where we consider two main areas of discussion (public and private). The concern for others dimension is related with elocutions that are the type of questions. An agent with high concern for others wants to know and understand other agent's point of view so he will ask more questions. An agent with low concern for others will ask fewer questions. The concern for self dimension is related with elocutions that are the type of statements. An agent with high concern for self wants to be heard and wants to share his opinion with other agents. An agent with low concern for self may not even have an opinion to share with others and therefore will make fewer statements.

The next step is to level each behaviour type for each of the dimensions considered. In Rahim and Magner's work they consider 2 levels for each dimension: high or low. However they point that the Compromising style of behaviour involves a "moderate concern for self as well as the other party involved in the conflict". This means that a third level could also be supposed which would be the moderate level. We use these 3 levels as a scale to classify each one of the behaviour type according to each dimension. We assume the classification of behaviour types presented in Table 2.

Table 2. Classification of conflict styles for each dimension proposed by Rahim and Magner [19].

Dimension	Low	Moderate	High
Concern for self	Obliging and Avoiding	Compromising	Dominating and Integrating
Concern for others	Dominating and Avoiding	Compromising	Integrating and Obliging

On one hand the obliging and avoiding behaviour types are placed at a lower level, the compromising type is placed at a moderate level, and the dominating and integrating types are placed at a higher level of concern for self. On the other hand the dominating and avoiding behaviour types are placed at a lower level, the compromising type is placed at a moderate level, and the integrating and obliging types are placed at a higher level of concern for others.

Like mentioned before we think that these two dimensions are related to the altruism facet and the distribution of each behaviour type in the levels that were considered could also be deduced just by looking at Costa and MacCrae [25] definition of altruism. In fact Rahim and Magner's analogy is very similar to the one used by Howard and Howard to classify each conflict theme. They consider that an aggressor has a low level of agreeableness (**-A**), meaning that an aggressor is someone that is unwilling to help others, and therefore has a low concern for others and their necessities and in return has a high concern for its own necessities. On the other hand a Submissive is someone with a high level of agreeableness (**A+**), meaning that is someone who is eager to help others, and therefore has a high concern for other necessities and a low concern for its own necessities. A Negotiator has a medium level of agreeableness (**A**) and therefore it is willing to help others but not as much as a submissive would because it still has a higher concern for its own necessities. For the avoider, he is not given an altruism level because an avoider does not care for others nor own necessities since he does not have any necessities and an avoider will not want to help others.

We then purpose 2 other dimensions of scope, based on the terminology of the remaining facets that were considered and that will be used to identify each behaviour. These dimensions are: resistance to change and activity:

- Resistance to change: This dimension is related to the compliance level of each agent, which means that an agent with a low "resistance to change" level will change his opinion easier compared with another with a higher level;
- Activity – This dimension is related to the activity level of each agent and how much effort he will put in the decision-making process, whether he will play a more active role and will take initiative to open discussion topics, ask questions and make statements in both public and private contexts and request to change opinions.

For the activity dimension, we associate this dimension with the areas of discussion as well as the agent's will to begin a new topic of discussion. This means that the more active an agent is then the more likely it will participate in both areas of discussion as well as want to create new topics of discussion. For the resistance to change dimension, we consider how agents will deal with other agent's requests. An agent with a high resistance to change will hardly ever change his opinion (unless the requested option can also provide a high satisfaction for that agent). On the other hand, an agent with a low resistance to change will accept other opinions more easily.

For the resistance to change and activity dimensions, like mentioned before, we based our scale with Costa and MacCrae [25] facets and therefore we consider three levels for each dimension: low, medium or moderate, and high.

The behaviour types for each dimension are classified as seen in Figure 3 and Figure 4.

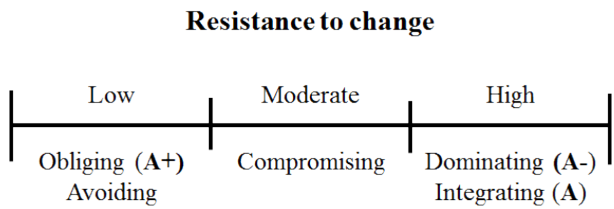

Figure 3. Classification of each behaviour type according to Resistance to Change Dimension.

Obliging and avoiding types are placed at a lower level, compromising type is placed at a moderate level, and dominating and integrating types are placed at a higher level for resistance to change.

Because we think resistance to change is related with the compliance facet there is a certain similarity with the concern for other and self dimensions since according to Costa and MacCrae [25] model, both altruism and compliance belong to the agreeableness factor. An individual with a low level of agreeableness (A-) is more aggressive and very hard to approach and convince. An individual with a medium level of agreeableness (A) is more approachable, and an individual with a high level of agreeableness (A+) is even easier to approach and to convince. Howard and Howard definition for each conflict theme also makes sense with the scale we have considered. An obliging individual because he has a high concern for others and their opinions is more likely to be convinced by others. On a medium level we find the integrating type with a medium level of compliance because he has a less concern for others compared with the obliging type; however it still is higher than the dominating's concern for others. The dominating is the type with the lowest compliance level and the hardest to approach and convince. The avoider does not have a compliance level because it does not possess its own opinion or interest and therefore is not even considered as a target that needs to be convinced or to be approached by others.

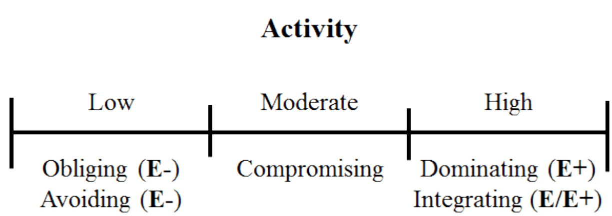

Figure 4. Classification of each behaviour type according to Activity Dimension.

Obliging and avoiding types are placed at a lower level, compromising type is placed at a moderate level, and dominating and integrating types are placed at a higher level for activity. This dimension is related to the Activity facet, with both obliging and avoiding types having the lowest extraversion which mean they will not be very active in the system. On the other hand, dominating and integrating types have the highest extraversion, and therefore will be to most active in the system.

To sum up the final table for all behaviour types and the corresponding levels for each of the dimensions defined in Table 3:

Table 3. Numerical classification of each behaviour type according to each dimension.

Behaviour Type	Concern for Self	Concern for Others	Resistance to change	Activity
Dominating	3	1	3	3
Integrating	3	3	3	3
Compromising	2	2	2	2
Obliging	1	3	1	1
Avoiding	1	1	1	1

It is important to understand that these levels are not absolute, which means that there are situations where an agent might act in a way that is not theoretically expected. This is why these values must be looked as low to high and not as 0 to 100. And this makes sense if we think of any real life group decision-making meeting. We often find participants that might have entered the meeting with a certain strategy, for instance, a participant that decided the best approach for that meeting would be to stay quiet at first, understand other participant's opinion and then gather a final opinion on the matter. Will this individual, however, follow this plan flawlessly? In some situations it could actually work however there are also situations where he might be forced to intervene earlier than he expected, either because another participant said something that does not make sense and if he does not say anything other participants might actually end up believing in that. Another situation could be the one where every participant or at least the majorities of participants share the same behaviour. If we imagine a group of avoiders trying to reach a consensus and everyone is waiting for a proposal to be announced, if no-one talks then there will be made no decision at all. But even in those cases there is always someone who ends up throwing a wild guess or suggesting something, even if at random, and then everyone will likely agree with that.

Therefore our model takes into account these special aspects of decision-making and is never assumed that a behaviour type will restrict an agent from performing a specific action. This means that every agent in our system has the same capabilities even if each agent has a different behaviour type. The behaviour type will only affect the probability of an agent to perform a specific action inside the system.

4. Conclusions and Future Work

Smart offices are a topic of study in the area of Intelligent Environments. They can be seen as the new trend of the traditional offices and decisions rooms. In order to simplify the process of group decision-making, there have been studied specific types of intelligent systems that will act in this kind of environments. The concern for representing decision-makers in a way that can support them with more intelligence has been increasing throughout the last decades. One of the strategies revolves around using multi-agent systems where an agent that represents a decision-maker is modeled with characteristics that allow doing so. These characteristics can be conflict styles, strategies, behaviour types, emotions, personality, etc. However, even though there is already a considerable amount of work in literature about some of these topics it is still hard to find models that can be correctly adapted to a context that requires the agents to represent and act accordingly to the style they have been modeled with. In this work we have identified as the main objective to define the most important dimensions that can differentiate the way agents act in the context of group decision-making and define for each behaviour type its level for all the dimensions considered.

We believe that the work here presented will open a new window towards the creation and the concrete definition of ways of acting for the agents that represent decision-makers through a conflict style. Firstly we adapted the conflict styles proposed by Rahim and Magner (integrating, compromising, dominating, avoiding and avoiding) to the group decision-making context and considered them as our behaviour types. Secondly we defined 2 dimensions which we consider important to define and differentiate the actuation mode of an agent modelled with each one of the different behaviour types (resistance to change and activity). We also adopted the 2 dimensions already proposed by Rahim and Magner (concern for self and concern of others) and the implicit classification in their work to classify each one of the behaviour type to each one of the dimensions (low, moderate and high). Thirdly, in order to classify each one of the behaviour type with each one of our new 2 dimensions we used the existing analogy between Rahim and Magner's work and the Howard and Howard's work. Then we used 2 facets from the Five Factor Model (activity and compliance) in order to be possible to correctly classify each one of the behaviour type in our scale.

We think that our future work can be very promising. Although the work here presented is based on deductions about scientifically proven studies, it is essential to notice if the future users (decision-makers) of this type of approach can understand what each behaviour style means whenever they select one to use. This way, our future work revolves around undertaking an in-depth study to observe how users perceive these conflict styles and if they are perceived according to their specification. This means that it is necessary to understand if when a decision-maker selects a conflict style, the agent acts according to his expectations. Besides that we also intend to define for each dimension (in case that our hypothesis can be validated) what will be the probability of occurrence as well its coefficient of variation. We also intend to connect each conflict style with certain elocutions to learn if there is homogeneity in the answers and that way draw valuable conclusions that can be applied to the definition of the behaviours.

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Progress Towards a Smarter Office via a Novel Intelligent System for Message Organisation by Unifying E-Mails & Phone Calls

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Abstract. This paper describes the background to a commercial software service called *Threads* that was developed to allow the sharing of various message types amongst a community of users - typically all working for the same organisation. Recognising the difficulty that many users have in finding even their own e-mail, a key design goal was to make the sharing and searching of large quantity of disparate messages easier than any existing personal mail client. The project has concentrated on developing a user interface that is easy to use rather than easy to program and, in so doing, has highlighted some interesting user perspectives. This paper discusses the typical user's needs and some of the features *Threads* uses to meet them. We then introduce a novel intelligent method for organising such messages automatically, according to statistics relating to less common words (called "keywords") which they contain. Initial experiments using this method are described, using both e-mail data from the parent company, and on the publicly available ENRON dataset of e-mails and phone calls. These preliminary results are interesting, but suggest the method as currently implemented is only suitable for semi-automatic classification, but not yet for fully automated allocations to projects. The paper concludes with a glimpse into the future prospects for message sharing and planned future developments to the *Threads* system.

Keywords. Message sharing; message organization, clustering, classification, searching, statistical similarity, e-mail; telephone messages

1. Introduction

Readers will no doubt be familiar with the situation where one struggles to find an important document or message when it is needed in a hurry. Although the user can remember roughly what the document or message was about, he/she may not be able to recall where it was saved, what it was called (or exactly what its subject line was), or who sent it or who were its recipients. Conventional methods of searching mailboxes or files require exact matches to at least part of a search term – so if the search term used is completely incorrect, the search will not return the desired result. One alternative approach is to search by content, but this still relies on finding an exact match somewhere in the target document(s) of at least part of the search term. Another, more flexible and powerful methodology is to compare how similar each document or

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message in the set being searched through is to a document containing a set of words expressing what the user believes are the most important ideas, summarizing the topic or theme of the desired target document(s). Similarly, we can obtain an indication of whether two documents have essentially the same theme or topic by comparing how similar they are. Usually this similarity (or level of difference) is measured in terms of statistics regarding the words each of the two documents contain, including words they share in common and words appearing in one but not the other. Some such metrics are based on relatively simple word counts, others make use of these counts to compute information theoretic quantities such as entropy, cross entropy, mutual information and perplexity [12]. The "target" need not necessarily be a single document or message – it could equally well be a set of document all relating to the same topic or theme, for example all about the same project. However, some words impart far more information than others. A high proportion of words in both text and speech are "function words", present to serve a grammatical function, but which carry very information about the theme of the document or utterance. Examples of such function words are "is", "has", "and", "but", "he" and "so". Most of these are very common across a wide variety of documents and conversations, regardless of their topic. In contrast, words which give a large amount of information about the topic of the text or utterance – so-called "content words" – tend to be much less common generally. Examples of this include "software", "contract", "algorithm" and "philosophy". Knowledge of which of these "content words", hereafter referred to as keywords, are in a given document, collection of documents or conversation, and how frequently, should be of great value in judging what the theme of the text or utterance is. Several authors [11, 12, 13] have noted that the distribution of words and their frequencies will vary greatly according to the type of document, speech or conversation under consideration and also its topic. The aim of this study is to investigate how easily and reliably a document or message can be classified – in our case, allocated correctly to a particular project – based on the statistics of keywords contained in the message, in comparison to other messages in the same, and in other, projects.

The *Threads* project [1] evolved from the needs of a small company to share information whose representation had, over a period of 20 years, changed from physical to digital [2]. As such, the storage medium moved from shared physical access - filing cabinets - to private digital access - personal e-mail accounts. While the digital form was easier to store and search, it often ended up locked in private user files. This applied primarily to company e-mail, but also extended to documents (e.g. invoices, quotations, etc.) that were not confidential and routinely needed to be shared amongst employees. As e-mail became the de-facto currency of communication, where most documents were shared as email attachments, sharing the e-mail became the key to re-establishing the collaboration ethos [3].

Various procedures (e.g. using shared IMAP folders) were put into place to allow the sharing of e-mail, but none was really successful. Apart from the fact that these required strict discipline on the handling of e-mail, they often fell down when the user had several e-mail accounts, or was working from remote locations. Special purpose software - such as bespoke e-mail clients - were universally shunned, and rightly so [4]. However, gains made by digitisation were often lost due to unnecessary possessiveness of individuals. A culture of non-sharing had evolved and become the norm.

Threads [1] is a web application which was designed to obviate the need for staff to treat their mail specially. It was necessary that staff continue to use their preferred e-mail client and not change their working practices. While this was largely a technical exercise, it demanded a staff culture shift back to the days where the default case was to share information. After some initial reluctance, staff soon realised that, with the appropriate controls in place, sharing could be liberating and few would return to the possessive "old days". Staff quickly understood the benefits of such openness because, with *Threads*, they could find things they previously could not and, just as importantly, they were able to devolve responsibility when it was useful. When digital telephony was introduced within the company [5], including it within the same *Threads* message handling framework was immediately successful: once phone calls could be seen in the same context as text-based messages - and vice-versa - the true power of message sharing was realised. That said, it became clear that it was important to unify digital messages such that, whatever the medium, they were presented to the user in a clear and natural way. This need for abstraction was a significant challenge.

Unification in any meaningful way requires context. The useful *information* content of each message is not always obvious or available. But once the message has some context, then there is often sufficient information available to decide if it is worth reading. For *Threads*, the context was a combination of the *project* or job to which the message related, and the people communicating through it.

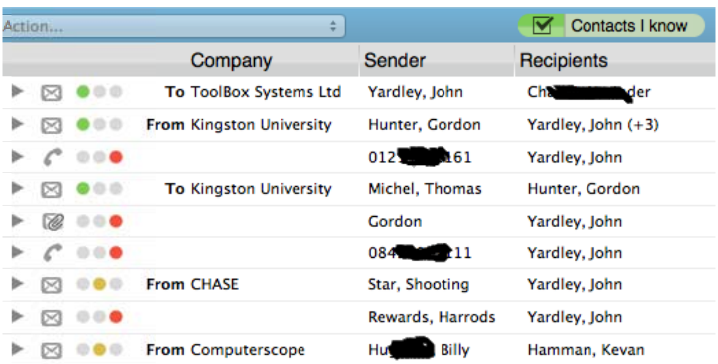

Figure 1. Threads interface and its "traffic light" system for flagging e-mails according to "Known contact" (green), "Probably known contact" (amber) or "Unknown contact" (red) allow easy and natural contact filtering. Telephone numbers and names of people not involved in the *Threads* project have been artificially obscured.

Although not a technical point, it is worth noting that, in our case, the integration of phone calls into *Threads* was never motivated by legal compliance or disclosure issues. Indeed, early on, we took the decision that calls would only ever be shared internally. What prompted this initially was to provide the knowledge that certain phone calls had occurred within the "thread" of a project - without regard to the actual content of these calls. With the company's conversion to IP telephony [5], and the availability of call recordings in digital format, it seemed an obvious next step to include these within our *Threads* system. Once they were freely accessible to all staff, users realised they no longer needed to rely on scribbled notes or their recollection of a call. With *Threads*, they could find a call just as they would an email, listen to it as many times as they wished, or pass the "link" to relevant colleagues.

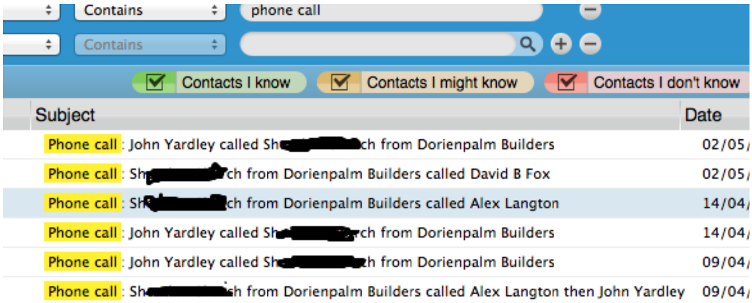

Figure 2. The subject line in *Threads*, showing the nature of the message (Phone call or E-mail), the caller (if known), the person called and the transfer path. Names of people not involved in the Threads project have been artificially obscured.

While it is not claimed that the *Threads* system developed is unique – see section 2 below - it was designed to be cost effective for very small groups - perhaps as few as two users. Early consideration was given to the needs of scalability and we see no reason why it cannot, in principle, support any arbitrary number of users.

2. Related Work

A considerable amount of work has been done in the past on clustering and/or classifying documents based on their lexical content. We sub-divide this section into three parts. The first focuses on methods and metrics for measuring the similarity (or difference) between two documents (or groups or documents). The second briefly discusses some approaches to clustering and classification based on those type of metrics, whilst the third subsection notes some applications by other authors which have some elements in common with the approach we take.

2.1. Document Similarity Metrics

The simplest statistics which give some summary indication of the content of a message are word frequency counts (or unigram statistics) and frequencies of sequences of n consecutive words, known as “n grams” [14, 18]. Messages which are very different in nature would be expected to have different distributions of their n gram statistics, and this approach has been used for text categorisation [23]. However, in order to use these thoroughly, a very large number of different counts would have to be computed – if we have a permissible vocabulary of V distinct possible words (where V is often several thousand), then there are V^n possible distinct n grams - and some probabilistic comparison would have to be performed to decide whether or not two messages belonged to the same class (or, in our context, project). Furthermore, as noted above, many common words provide very little information about the content or theme of a message, so the useful vocabulary of keywords may be much smaller than V. Any really practical and useful lexically-based clustering and classifying method will group messages or documents according to the words they contain : messages or documents containing largely the same distinct words should be put into the same cluster, bearing in mind how common or distinctive each word is. This approach has been used by Sekine [24] and Iyer & Ostendorf [22], who defined a “similarity measure” between two documents according to the number of distinct words in each, the total number of words in each, and the number of documents (or messages) under consideration overall.

An alternative approach is to use a similarity metric based on the mathematical definition of information, related to the statistical concepts of entropy and perplexity of a test document or message with respect to a statistical "model" of the distributions of words in a reference document or group of documents. This approach was used by Carter [19, 20] and Clarkson & Robinson [16, 21], taking the "distance" between a given test document and a cluster of documents to be the perplexity of a unigram model (one based on the statistics of individual words) derived from all the text in that cluster, with the current cluster C and the test document D respectively, $N_C(w)$ and $N_D(w)$ are respectively the number of times that the word w occurs in the cluster and the test document, and $\underline{w}^{(D)} = (w_1, w_2, \ldots, w_{Nc})$ is the test document written as a word string, then from the definition of perplexity, the required unigram model perplexity can be calculated as :

$$PP_1 = \left(P(\underline{w}^{(D)} \mid C) \right)^{-1/N_D} = \left[\prod_{i=1}^{N_D} P(w_i \mid C) \right]^{-1/N_D}$$

by the assumed independence of unigram probabilities [16, 21]. This perplexity can be interpreted as the average number of possibilities for a task of guessing the next word in a sequence, given the sequence so far. High perplexity indicates low predictability, and vice versa. The values of $P(w_i \mid C)$ for each word w_i in C can be estimated from the number of times each word has been observed in C, bearing in mind that even if a particular word has never been found in that cluster, this does not imply that this word could never be found in a document which should be in that cluster – no word should be given a probability which is exactly zero. Note that, unlike the lexically-motivated metrics discussed in the previous paragraph, this perplexity metric has a relatively low value for similar documents or clusters and higher values for dissimilar ones. Although this metric is less *explicitly* based on the particular words within a document cluster, it is still *implicitly* highly dependent on them – since the relevant entropy or perplexity values are dependent on word probabilities given by the unigram word models for these clusters.

A practical solution retaining a clear connection with the actual lexical content of each document or message is offered by the "relevance weighted distance" metric proposed by Robertson & Sparck-Jones [8]. This takes account of how common a given word is in both the "test" and "reference" documents (or group(s) of documents), how common that word is generally, and how long the documents (or group) being considered are – longer documents tend to contain more distinct words. Their metric has three components :

(i) a "collection frequency weight", which emphasizes words which are generally less common, and hence provide more useful information about the content of the two documents :

$$CFW(i) = \log(\mathrm{N}) - \log(n_i)$$

where n_i is the number of documents (or turns) containing the word labelled i and N is the total number of documents under consideration.

(ii) "term frequencies", related to how frequently each particular word occurs within a given document. A word which is normally rather uncommon which occurs very frequently in a particular document is likely to be highly characteristic of that document – perhaps relating specifically to the topic of theme of that document. The term frequency, $TF(i,j)$, of a word labelled i in a document labelled j is defined to be the number of times the word i occurs in that document j.

(iii) the document lengths – all other factors being equal, any given word is more likely to appear in a long document than in a short one. Likewise, a longer document will tend to contain more different words than a short document. A "normalised document length", $NDL(j)$, of a document j is defined to be the total number of words (not necessarily distinct) in document j divided by the mean length (in words) of the documents under consideration.

Robertson & Spärck-Jones [8] then combine these factors to give an overall measure of how similar two given documents are. The "Combined Weight" (or "combined relevance weight") for term (word) i with respect to document (or group of documents) j is defined as :

$$CW(i,j) = \frac{CFW(i)\ .\ TF(i,j)\ .\ (1+K_1)}{\left[TF(i,j)\quad +\quad K_1\ .(\ (1-b) + b.NDL(j)\ )\right]}$$

where K_1 and b are adjustable parameters. K_1 adjusts the influence of the term frequency – setting K_1 to zero removes any influence of TF on CW, whereas the higher the value of K_1, the stronger the influence of TF. Robertson & Spärck Jones [8] reported that use of $K_1 = 2$ had proved to be effective in tests on text documents such as news items and government reports. The parameter b, restricted to values between 0 and 1, adjusts the influence of both document length and term frequency on CW. If $b = 0$, then it is being assumed that documents tend to be long if they contain many distinct topics, whereas if $b = 1$, the length of documents is assumed to be due to repetitiveness and verbosity. Robertson & Spärck Jones [8] suggested that values of b around 0.75 had been found to work well in their studies. Further discussion of this metric and its application to text clustering can be found in [8, 10].

2.2. Clustering and Classification Methodologies

There are two principal types of approaches to machine learning for classification and clustering items : supervised and unsupervised. In the case of supervised learning, a set of features of each item are identified, and a set of examples for which the correct classification is known are used to determine correlations or other relationships between the features and the correct category, and hence learn a mapping which will predict the correct category for an item given the values of those features for that item. Examples of supervised machine learning techniques and tools are Bayesian (probabilistic) learning and Multi-Layer Perceptron (MLP) Artificial Neural Networks [25]. Unsupervised approaches, on the other hand, do not require training examples for which the correct classification is known, but they do require a metric for measuring the similarity or difference between example items. Items can be grouped together, or clustered, based on their similarity, or classified according to which cluster they are most similar to. Example unsupervised approaches to clustering & classification include the k-means algorithm [9] and its fuzzy variant c-means clustering [37], Kohonen's Self-Organising Map (SOM) [15], and variants such as the Plastic Self-Organising Map [26], Growing Hierarchical Self-Organising Map (GHSOM) [27], and Growing Neural Gas [28] networks. Decision Tree approaches can work in either a supervised or unsupervised manner. Whichever approach is most appropriate will depend on the nature of the situation and whether sufficient categorized (or "labelled") examples and/or a suitable similarity metric are available. Supervised methods require a "training" or "learning" phase, where the labelled examples are used to train a model, which can subsequently be used to cluster or classify previously unseen examples, for which the correct classification may or may not be known. However, once the similarity metric has been specified, an unsupervised method does not require any training phase, but can be applied to the clustering or classification of examples straight away.

2.3. Other Systems for Message Clustering and Classification

The *BuzzTrack* system [35] was devised as an add-on to work in conjunction with the Mozilla Thunderbird e-mail interface, and groups e-mail messages by topic. The authors take care to distinguish between the concepts of *topic* and *thread* – documents belong to the same topic if they relate to the same idea, action, event, task etc., whereas a message thread (under their definition) consists of a chain or messages in a common sequences of replies and forwardings. Thus, with respect to these definitions, a topic may span several threads and/or a thread may be distributed over several topics. That project identified the topic of a message, and clustered messages by topic, using a metric based on term frequencies, document frequencies and a similarity function analogous to the Pearson correlation coefficient, with features selected using an information gain criterion. The applications of this system focused on new topic detection and topic tracking – the latter referring to classification of new e-mails according to whether they do or do not relate to the targeted topic. *E-MailSift* [36] is a system which uses the structure, as well as the content, of an e-mail in order to classify it. Other approaches previously used include [29-34]. Drezde et al [30] have taken an activity-based approach to e-mail classification, sorting by the general nature of the activity (e.g. research & development, sales, finance, recruitment) to which the message relates. Bellotti et al [38] and Whittaker et al [34] have classified messages according to the tasks with which they are associated, whilst Sudendran et al [29] have taken an approach using the concept of "personal topics" of messages, where each message is associated with a topic from a list defined by the user. Neustaedter et al [31, 32] adopted an "e-mail triage" approach, using knowledge of social relationships between senders and recipients to identify e-mails likely to be important, likely to be less important, or junk.

3. (Semi-)Automated Message Clustering & Classification for *Threads*

The aim of this study is to investigate how easily and reliably a document or message can be classified – in our case, allocated correctly to a particular project – based on the statistics of keywords contained in the message, in comparison to other messages in the same, and in other, projects. This is with a view to eventually implementing automated – or at least semi-automated, where a particular project would be suggested to a human user as being appropriate for filing a new message, as yet unallocated to any project –

clustering of messages into groups relevant to different projects, in a reliable way with few errors, within the *Threads* system. For this preliminary evaluation, we have used the document similarity metric of Robertson & Sparck-Jones [8] discussed above, and two datasets of corporate e-mail messages which had already been manually allocated into projects. The first is a set of 750 e-mails from the company, JPY Ltd., who created *Threads*, the other is a subset of the publicly-available database of e-mails of the former U.S. energy company ENRON. Using two datasets, relating to two very different companies, in this way allows us to investigate both the utility and robustness of our approach and metric. In both cases, residual text from previous e-mails in a "chain" (due to forwarding, or replying to, previous messages) was removed to avoid biasing the data through spurious replications of identical pieces of text in several different e-mails from the same "chain". In each case, every e-mail used came from a known project. The aim of this experiment was to test whether clustering messages based on their keyword content could be a viable and reliable way of associating messages with projects, either fully automatically, or "semi-automatically" – i.e. making a suggestion of an appropriate project in which to file each message to a person classifying messages.

3.1 JPY Dataset

JPY Ltd. is a small software development, distribution and consultancy company, based in a South-Western suburb of London, with around 10 employees, who need to communicate with each other, their suppliers, customers and collaborators by e-mail on a regular basis. The nature of the company means that several of the employees, and possibly the directors, will be involved in the same project, and hence benefit from the ability to access and search all e-mails relating to a particular project in which they are involved. The JPY dataset used here for testing our method consisted of a total of 750 e-mails, each one relating to exactly one of 20 projects, either allocated manually by a member of staff involved with the project, or by means of an unambiguous project identifier contained in the e-mail. Those 20 projects each contained between 10 and 100 e-mail messages, of varying lengths.

3.2 ENRON Dataset

The ENRON Corporation of the U.S.A. was, until it went bankrupt in 2001, one of the World's largest energy providers and employed around 20 000 people. However, the bankruptcy triggered an investigation, which led to a major fraud trial, and the U.S. legal authorities required scrutiny of all still extant ENRON e-mails and recorded telephone conversations [7]. This resulted in a large corpus of some 250 000 e-mails, relating to 350 projects, involving around 28 000 contacts from 1500 companies, plus 76 recordings (with transcriptions) of telephone calls being available in the public domain [17]. For the purposes of this experiment, in order to use a sample of comparable size to the JPY dataset, we have taken a sample of 750 of these ENRON e-mails (of varying lengths), from 20 different projects, with between 10 and 100 messages per project. It is assumed that the messages were correctly allocated to projects by ENRON staff.

3.3 Pilot Study Clustering & Classification Experiment

We performed a keyword-based cluster-classify experiment on each e-mail from each sample. We allocated a total of 20 clusters, one for each project. We “seeded” each cluster by one e-mail, selected at random, from the project we wished it to represent, and the keywords extracted from that e-mail. For each of the remaining 749 e-mails, we also extracted the keywords, and then searched for the “most similar” cluster to it, in terms of keyword content, using Robertson & Sparck-Jones’ relevance weighting metric [8] as a measure of “distance” between e-mails. Note that, although similar to k-means clustering [9], this approach is not identical to it since, in our method, each cluster must contain the e-mail it was seeded with at all times. Furthermore, the “typical keywords” for each cluster are determined by that first seed message, rather than those most truly representative of the cluster. These issues will be addressed in subsequent experiments but were chosen here to simulate a “live” e-mail environment. For each “test project”, each one of the 749 e-mails not used as the seed for that project was either allocated to that project or not, according to which project it was deemed to be “most similar” to. In principle, all 749 e-mails could get allocated to one project, or only one (namely its seed) might get allocated to a given project. The project A to which each e-mail was allocated was noted, and compared with the actual project B from which that e-mail had originally been taken. If these matched (i.e. if A = B), then that was deemed to be a “True Positive”. If an e-mail was erroneously allocated to project A, then it would count as a “False Positive” (FP) for that project, whereas one which should have been allocated to project A (i.e. did actually come from that project) but was not was treated as a “False Negative” (FN) for project A. E-mails correctly identified as not belonging to project A were “True Negatives” (TN). Summary performance measures, explained below, for these experiments, are given in Table 1.

TABLE 1. Summary performamce results of our method applied to both JPY and ENRON datasets, over 750 e-mails from 20 projects in each case.

DATASET	AVERAGE	ACCURACY	PRECISION	RECALL	SPECIFICITY
ENRON	Project-by-Project	0.9056	0.6611	0.1573	0.9521
	Overall	0.9056	0.0560	0.0560	0.9503
JPY	Project-by-Project	0.9315	0.3086	0.3930	0.9637
	Overall	0.9315	0.3148	0.3147	0.9639

The following summary performance statistics were computed for each project, and overall :

$$\text{Accuracy} = (TP + TN) / (TP + TN + FP + FN)$$

Accuracy is the fraction of all the items, which *were correctly* allocated, either to that project or to another.

$$\text{Precision} = TP / (TP + FP)$$

Precision is the fraction of all the items that *were* allocated to that project which *should* have been allocated to it.

$$\text{Recall (or Sensitivity)} = TP / (TP + FN)$$

Recall is the fraction of all the items that *should* have been allocated to that project which *were* actually allocated to it.

$$\text{Specificity} = TN / (TN + FP)$$

Specificity is the fraction of all the items that *should not* have been allocated to that project which *were* actually *not* allocated to it.

The results of our experiments, both over all e-mails in each dataset, and averaged on a project-by-project basis, are summarized in Table 1. The results show similar trends for both datasets, although the "precision" and "recall" over all the e-mails are rather higher for the JPY dataset than for ENRON data. It can be observed that our method performs rather better according to some indicators than others. This is because, when the focus is on any particular project cluster, the method usually (and correctly) does not allocate the majority of e-mails to that cluster, resulting in a high number for TN. However, it does sometimes give rather large numbers for FP and FN. The indicators which emphasise these rather than TN will suggest a weaker performance. More FP and FN were, on the whole, obtained for the ENRON data than for the JPY e-mails, explaining the poorer precision and recall for the former. One interesting feature, observed for both datasets, but more markedly so for the ENRON data, is that the method produced one very large cluster, which we nicknamed "the dustbin", containing a very large number of FPs. We believe that this cluster is used to collect e-mails which show little similarity to any of the "regular" clusters, and hence get treated as garbage. A similar feature was observed by Hunter & Huckvale [10] when they were clustering transcribed dialogue data.

The results so far indicate that the method and similarity metric, as currently implemented, can provide a useful suggestion to a human user as to which project or cluster is correct for a given e-mail (i.e. it could be helpful for semi-automatic message classification), but will require substantial improvement before being used as a fully automatic classifier.

4. Conclusions and Future Work

In this paper, we have introduced our software tool, *Threads*, for corporate message sharing – both text based (e-mails, etc.) and recordings of telephone calls - within a company, illustrating how it allows users to search or browse for messages, organized by project, sent or received either by that user or by others within the company or team. We have then investigated the possibility of using statistics of relatively rare words for automated classification of messages into clusters, each associated with a particular project. The results of experiments, carried out on e-mail data both from the company, JPY, which created *Threads* and from the much larger (now no longer extant) company ENRON, have showed promise, but suggest that our method, as currently implemented, is not yet suitable for fully automated allocation of messages to project clusters.

We propose to extend the range of experiments carried out, implementing a fully dynamic approach to classification, using k-means clustering [9] or a method such as a Self-Organising Map (SOM) [15], or one of its many variants [26, 27, 28]. Alternative similarity metrics, possibly based on the concepts of entropy and information [10, 16], should also be explored. Confusion matrices, indicating messages from which projects tend to get classified as belonging to which other projects, should also be computed.

One feature of *Threads* which has not yet been included in these experiments, and which would be necessary if the *Threads* system is to achieve its full potential, is the integration of recordings of telephone messages with text e-mails within appropriate projects, in a way which will allow (semi-)automated clustering, classification and searching of both text and speech-based messages. The authors are aware of the opportunities which speech technology – notably automatic speech and/or speaker recognition – could provide for potential enhancements to the *Threads* systems in order to provide at least keyword summaries of telephone messages, allowing their clustering, classification and search by theme or keywords. Such developments are currently being investigated.

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Intelligent Environments Approaches Applied in Water Management

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Abstract. Recently, we are in the époque of sophisticated *Ambient Intelligence (AmI)* applications, mainly based on utilisation of wide sensor networks together with advanced AmI approaches. If we concentrate on environmental (that is, open space or outdoor) applications, there is just a few of them, although basically focused on environmental monitoring, that enable more functionalities than just collecting environmentally related data and passing them to further elaboration. In our paper we intend to go further on with the ideas how environmentally oriented wireless sensor networks used in "large-scale" throughout the open natural environment could be enhanced using some recent AmI approaches in order to be beneficial in preventing primarily environmentally related problems, if not even disasters. We focus our attention on the area of water management with accent on two critical water related problems: floods management and drought-stricken periods. We suggest a concept of an approach how to solve a particular water management problem in Czech Republic using large-scale ambient intelligence approach enhancing thus wireless sensor network focused on environmental monitoring.

Keywords. Ambient intelligence, wide area sensor networks, large-scale applications, intelligent outdoor spaces, outdoor workplaces

1. Introduction

Recent sophisticated *Ambient Intelligence (AmI)* applications, mainly based on utilisation of wide sensor networks together with advanced AmI approaches, deserve to be used widely because of their benefits for big palette of users. However, when focusing on environmental (that is, open space or outdoor) applications, there is just a few of them, although basically focused on environmental monitoring, that enable more functionalities than just collecting environmentally related data and passing them to further elaboration. Such applications are closely related to the notion of "Large-scale Ambient Intelligence", firstly introduced in [1].

According to [2], recent advances in micro-electro-mechanical systems and in low-power wireless network technology have created the technical conditions for building multi-functional tiny sensor devices, which can be used to observe and to react according to physical phenomena of their surrounding environment. Wireless sensor nodes are recently evolved in low-power devices equipped with processor, storage, a power supply, a transceiver, one or more sensors and if necessary, also with an actuator. Several types of sensors can be attached to wireless sensor nodes. These wireless sensor devices are small and they are cheaper than the regular sensor devices.

As Akyildiz and others [3] pointed out, the wireless sensor devices can automatically organize themselves to form an ad-hoc multi hop network. Wireless sensor networks may be comprised by hundreds or thousands of ad-hoc sensor node devices, working together to accomplish a common task. Self-organizing, self-optimizing and fault-tolerant are the main characteristics of this type of network.

Environmental monitoring applications can be categorized into indoor and outdoor monitoring [2]. According to them, indoor monitoring applications typically include buildings and offices monitoring. These applications involve sensing temperature, light, humidity, and air quality, but also fire and civil structures deformations detection. From our point of view, outdoor monitoring applications are much more interesting and still having a serious potential for further exploitation. Outdoor monitoring applications include chemical hazardous detection, habitat monitoring, traffic monitoring, earthquake detection, volcano eruption, flooding detection and weather forecasting, among others. Environmental wireless sensor networks also have found their applicability in agriculture with soil moisture and temperature monitoring as the most important applications.

In our earlier papers [4], [5] and [6] we started with some contemplations related towards possibilities of using ambient intelligence approaches in water management. In our recent papers [7], [8], [9] or [10] we concentrated our research on several scenarios how outdoor oriented applications of environmental wireless sensor networks could be enhanced by recent approaches from the area of Ambient Intelligence in order to enable an outdoor environment to be a smart environment in a well-defined sense.

In this paper, we present some contemplation about possibilities for outdoor large-scale ambient intelligence focused on areas, where environmental catastrophes with disastrous effects could appear, with main accent on the water management area. We define a particular practical problem and an outline of its solution .

2. The Problem

One of the important problems that seem to be suitable for solving by large-scale ambient intelligence approaches is monitoring a river watershed. The aim of a project investigated a couple of years ago [4] was the development of a system that could help the watershed managers who make decisions about the most suitable manipulations on the reservoir Nyrsko and on the river Uhlava in South-western Bohemia in the Czech Republic. Although the reservoir Nyrsko is relatively small (approximately 142 000 m2) and the river Uhlava is no longer than 110 km, the problem of reservoir and river control is interesting enough, because Nyrsko is the only resource of drinking water for over 180 000 inhabitants of the town Pilsen. As this resource of water lays 100 km up on the stream from Pilsen, the task of effective and economical manipulations is non-trivial. The main obstacle comes from the time delay between the manipulation on the reservoir and the manifestation of the manipulation in Pilsen (3-7 days). That is why all requirements for reducing or increasing of the consumption of water from the river Uhlava have to be defined in advance. In the same time the weather forecasts for several next days have to be taken into account in the process of manipulation formulation, because heavy rainfalls or dry periods can radically change the flow rate in the river and its inflows and thus the significance of manipulations gets even clearer. The other kind of obstacles is related to the pursuit of fulfilling contradictory requests of different customers of the water management company, who are owners of electricity power plants, fishers, managers of water sport events, industrial companies that consume water from the river Uhlava etc. The whole situation is schematically depicted in Fig. 1.

Fig. 1. Scheme of the real watershed situation.

The developed system [4] was capable of supporting watershed managers' decisions about the manipulations on the reservoir Nyrsko and on the river Uhlava. However, a few years ago, we can think about an enhancement of the system by adding a functionality of producing early warning messages in critical situations such as approaching storms with possible flesh floods, or very fast gradient of the river surface level increase possibly resulting in a flood danger. This paper describes some possible approaches how adding of these new functionalities could be possible.

3. Related Works

3.1. Wireless Sensor Networks

When thinking about enhancement of the above mentioned system aiming of a river basin dispatchers' decisions support, the first possible approach seems to be in employing a large-scale intelligent sensor network as a basis for an enhanced system.

Tremendous effort has been devoted recently to the area of sensor networks and their important applications, as mentioned in [11] or [2]. A wireless sensor network is usually a combination of low-cost, low-power, multifunctional miniature sensor devices consisting of sensing, data processing, and communicating components, networked through wireless link [11]. In a typical application, a large number of such sensor nodes are deployed over an area with wireless communication capabilities between neighbouring nodes.

There is a number of works dealing with technical possibilities of sensor networks. Loke [11] lists a number of results, oriented on context-awareness of sensors and sensor networks. The idea behind is, that if sensors could know more about their own context, then they could adapt their behaviour and function only when needed and to the extent adequate to the current circumstances. This aspect can be important also for power consumption by the sensor. A lot of work has been done by [12], [13], [14], or [15], an interesting yet a bit older survey was written by Akyildiz et al. [3], but there is also a more recent survey [2].

3.2. Large-Scale Environmental Applications

Among a number of recent interesting environmental applications, we can mention the FieldServer Project [16], and the Live E! Project [17].

The FieldServer Project is oriented on development and networked applications of so-called Field Servers. A Field Server [16] is a wireless sensor network that will enhance the monitoring of environmental factors by allowing sensing nodes to be located at precise locations in fields, reducing overhead installation costs, and allowing for real-time data collection. In Japan, Field Servers were developed for applications at farms. They produce real-time images for security guards, and environmental data for farming. Scientists such as agronomists, physiologists and ecologists can exploit high-resolution real-time images in order to react on any specific situation that deserves or requires some intervention in the environment. Many types of Field Servers have been developed up to now.

The Live E! Project [17] is an open research consortium to explore the platform to share the digital information related to the living environment. Using the low cost weather sensor nodes with Internet connectivity, a nationwide sensor network was deployed [17]. The network has accommodated more than 100 stations. The application of this weather station network is intended for disaster protection/reduction/recovery and also as educational material for students.

According to [18], watershed management administers water resources within a watershed for different water users. The ultimate purpose of watershed management plan is to maximize the profits of different users meanwhile reducing the possible conflicts that might occur between them. Watershed management can be very efficiently modelled using multi-agent systems, nevertheless, there is just a few works taking into account also catastrophic situations (see, e.g., [19]).

Cardell-Oliver and her colleagues [12] proposed a novel reactive soil moisture sensor network that reacts to rain storms in such a way, that frequent soil moisture readings were collected during rain (approx. every 10 minutes), but less frequent readings (once a day) were collected when it is not raining. The network includes a node with a tipping bucket rain gauge sensor and, in another part of the landscape, a group of nodes with soil moisture sensors. The node monitoring rain is separated from the nodes monitoring soil moisture, and yet these nodes need to share information, whilst minimizing the time spent sending, receiving and listening to messages.

Some attempts to apply the Ambient Intelligence approaches to disaster management in general are described, e.g., in [20], where an architecture is proposed aiming to help in decision-making processes in disaster management. Here, several different environments are considered, namely a smart house, an airport and a paramedics unit doing assessing a victim of a nuclear disaster.

One of the most significant drivers for wireless sensor network research is without any doubts environmental monitoring. Its potential will not only enable scientists to measure properties that have not previously been observable, but also by ubiquitous monitoring the environment and supplying the related data to relevant supervising bodies they can create a basis of early warning systems for various environmental disastrous situations and their management. As it is in [21] pointed out, the relatively low cost of the wireless sensor networks devices allow the installation of a dense population of nodes that can adequately represent the variability present in the environment. They can provide various risk assessment information, like for example alerting farmers at the onset of frost damage. Wireless sensor networks based fire surveillance systems were designed and implemented, as well. They can measure temperature and humidity, and detect smoke following by early warning information broadcasting [22]. Sensors are able to consider certain dynamic and static variables such as humidity, the type of fuel, slope of the land, the direction and the speed of the wind, smoke, etc. They also allow determining the direction and possible evolution of the flame front.

However, apart from other similarly serious environmental disasters, floods are responsible for the loss of precious lives and destruction of large amounts of property every year, especially in the poor and developing countries. A lot of effort has been put in developing systems which help to minimize the damage through early disaster predictions (see, e.g., [23]). On the other hand, as drought periods, opposite to floods, cause lot of damage every year as well [24], also this problem deserves highest effort. Interesting solutions to the problems can be found e.g. in [25], [26], or [27].

Some other interesting related applications can be found, e.g., in [28] and [29]. The first one is devoted to assist workers in a coal mine in China, contributing to the higher security of their work. The second one describes an interesting case of a wireless sensor network supporting the safety of geophysicists working near a living volcano. A wireless sensor network was deployed to monitor eruptions at Tungurahua volcano, located in central Ecuador. This single hop network is constituted by five sensor nodes where three of them are equipped with a specially constructed microphone to monitor infrasonic signals originated by volcanic eruptions. The data collected by the sensors are sent to a local sink and then relayed over radio links to a computer located nine kilometres away.

In SensorScope project [15], two networks were deployed. The first network was installed in Wannengrat (Kanton Schwyz, Switzerland) in order to study environmental processes involving snow. The second network was installed on a glacier in the canton Valais, Switzerland, to measure air temperature, air humidity, surface temperature, wind direction and speed, precipitation and solar radiation. Seven nodes were used in the first deployment and sixteen nodes in the second.

The sensing nodes and the sink node uses TinyOS operating system. A multi-hop network wass used to support communications between the sink node and the sensing nodes. Sensing stations regularly transmit collected data (e.g., wind speed and direction) to a sink, which uses a gateway to relay the data to a server. Data is published on a real-time Google Maps-based web interface and on Microsoft's SensorMap website.

A very interesting and to our issues relevant paper was published by Vescoukis and others [30]. It was motivated by the fact, that there is a great increase of natural disasters (e.g., forest fires, flooding, landslides) which has stimulated a great research interest in developing smart and intelligent Environmental Information Management (EIM) Systems. These systems should be able to collect, process, visualize and interpret geospatial data and workflows of added-value applications so as to support decision making in case of emergency. It is quite clear that natural disasters pose a great threat to people's lives and their properties while they present a negative impact to the economies. In [30] a novel Service Oriented Information System is proposed that seems to be proper for Environmental Information Management, as well as for planning and decision support in case of emergency. The proposed architecture was designed in close collaboration with real world stakeholders in civil protection and environmental crisis management, and has been implemented as a real system, with applications in forest fire crisis management.

3.3. Outdoor Activities Support

In order to support a person's activities outdoor, her geographic location must be identified as an important contextual information that can be used in a variety of scenarios like disaster relief, directional assistance, context-based advertisements, or early warning of the particular person is some potentially dangerous situations. GPS provides accurate localization outdoors, although is not very useful inside buildings. Outdoor to indoor and vice versa activities localization was investigated e.g. in [31] by a coarse indoor localization approach exploiting the ubiquity of smart phones with embedded sensors.

Some our recent results in this area can be found also in [8], [9], [10], or [32].

Outdoor acting person's support should provide relevant and reliable information to users often engaged in other activities and not aware of some hazardous situations that he or she could possibly encounter. There are only a small number of attempts to solve the related dangerous situations that can be very briefly described using the following scenario:

A user appears in a natural environment performing her/his working mission, a kind of leisure time activity (hiking tour, mountaineering, cycling, etc.), or because of being an inhabitant of the area. A sudden catastrophic situation (storm, flash flood, debris flow, etc. could put the person in a risky, if not a life endangering situation. A federated wireless sensor network is ubiquitously monitoring the area and estimating the possible appearance of a dangerous situation. If necessary, the network will proactively broadcast an early warning message to the user, offering her/him related navigation services supporting escape from the dangerous situation.

In the literature, there is only a few works oriented on a kind of a service to the potentially endangered persons in a natural environment; however, this service is never such complex as in our scenario.

For instance, there are some attempts of preventing children from potentially dangerous situations in an urban environment. Probably the first ubiquitous system to assist the outdoor safety care of the schools kids in the real world is described in [33]. The research described there was focused on designing a ubiquitous kid's safety care system capable to dynamically detect possible dangerous situations in school routes and promptly give advices to kids and/or their parents in order to avoid or prevent from some possible dangers. To detect the dangerous situations, it is essential to get enough contexts of real environments in kids' surroundings. This is based on two basic assumptions: (1) a big number of sensors, RFIDs, tags and other information acquisition devices are pervasively distributed somewhere in and near school routes, and (2) a kids should carry or wear some devices that can get surrounding context data from the above pervasive devices.

A number of papers are devoted to various solutions for tourist assistance, mainly oriented on context-aware tourist navigation on their routes. The usual approach (see, e.g. [34] or [35]) is in deployment of intelligent agents, which collectively determine the user context and retrieve and assemble a kind of simple information up to multi-media presentations that are wirelessly transmitted and displayed on a Personal Digital Assistant (PDA). However, these tourism oriented applications are usually deployed for the navigational purposes, without having capabilities of warning the user from potentially dangerous situations that can appear during their routes.

4. Possible Agent-Based Solutions

Ambient intelligence environments may be considered as strongly related with multi-agent systems in that they can be adequately modelled using multi-agent systems of various types.

The organizational model *Aalaadin* [36] has been quite often used when speaking about participative water management support. The core concepts of the *Aalaadin* are agent, group and role [37]:

- An agent is defined as an active communicating entity, no constraints other than those triggered by the ability to play a role or not.
- A group is defined as a set of agents.
- A role is defined as an abstract representation of an agent function, service or identification within a group. The role encapsulates the way an agent should act within a group. Roles are local to groups.

According to [37] an agent can simultaneously play different roles in different groups, i.e. groups can freely overlap. An agent can enter or leave groups by acquiring or resigning a role, that is, groups are dynamic structures. Groups represent organizational levels and roles represent functions within these levels; through the roles it is handling, an entity gathers information from the different processes it is involved in without concern about eventual scale or time heterogeneity of these processes.

If we adopt this approach further on, we get a potential of using ambient intelligence concepts based on multi-agent models, usable for enhancing e.g. a river watershed by various AmI artefacts capable of ubiquitous communication and helping intelligently to manage the watershed.

Based on ideas presented by Iqbal and others in [1], we can think about Large-scale Ambient Intelligence as a large set of geographically widely distributed intelligent sensor resources with the main purpose of increasing significantly intelligence of various segments of real nature. By a smart sensor resource we shall mean a kind of ambient artefact, namely a combination of an advanced sensor with ubiquitously computing and communicating processor integrated with the sensor. They purpose will be given by their main tasks, so that a number of their specific types could be possible. Let us mention some examples:

- smart water level guards;
- smart soil humidity sensors;
- smart forest fires guards;
- smart wind velocity sensors;
- and a couple of others.

Speaking about guards, we shall mean special kind of intelligent sensors applicable namely for early warning purposes in such cases, when e.g. the water level increase achieves some given gradient, or when temperature in a segment of a forest overreached the given level. In such a case the intelligent sensor resource will communicate a kind of alarm which will be propagated through whole sensor network and immediately elaborated further on by the responsible parts of the network.

Multi-agent architectures seem to be applicable here, as it is common in the case of large networks of sensors. We can tract various types of intelligent sensors and guards as agents with appropriate level of intelligence, recent dispatchers or even dispatching centres can be modelled as supervising agents (e.g., river basin management dispatching centres or fire brigades dispatching centres, etc.).

Certainly we can imagine a number of various kinds of guards and sensors. Let us present some examples, which are technologically feasible and frequently used in large-scale wireless sensor networks:

- *water level guards*, monitoring surface water level, or even groundwater level and watching over potentially dangerous or at least unusual situations.
- *water quality guards*, monitoring surface and groundwater quality and watching over possible contaminations or pollutions.
- *air pollution guards*, monitoring air quality, watching over possible pollutions.
- *wind velocity sensors*, monitoring wind velocity and watching over potentially dangerous situations.
- *soil moisture sensors*, measuring level of soil humidity, e.g. in forests, or in a river watershed, aiming at monitoring the degree up to which is the land segment saturated by water, and measuring the capacity of further possible saturation.

Of course, other kinds of intelligent sensors integrating ubiquitous monitoring (computing) of measured parameters with ubiquitous communication with other sensors – agents – in the area are possible as well.

We believe that the main application area for large-scale ambient intelligence will be any kind of prevention, connected with early warning facilities. Such areas as fire prevention, water floods prevention and early warning, or accident prevention in urban traffic could be clear candidates.

In water floods prevention area we can imagine the usage of the following agents:

- water level monitoring agents;
- land segments saturation (moisture) guards;
- water reservoir handlers;
- supervising agents.

The concept of our solution to the problem described in the second part of this paper consists of the following steps:

Establishing a large-scale wireless sensor network, consisting of already installed water level guards, completed by a number of sensor subnetworks, composed from soil moisture guards, situated in those land segments that are already known as critical from the soil saturation point of view.

The established large scale wireless sensor network will be embedded in a multi-agent architecture, where the particular sensor subnetworks of various types will play roles of group of agents in the multi-agent architecture.

The special roles are assigned to manipulating agents, as are, e.g., water reservoir Nyrsko handlers, or three river weirs manipulators.

The whole system is designed as hierarchical, as there is a number of concentrators, that is agents collecting the data as well as messages from the groups of agents defined in the step 2. These concentrators then communicate mutually as well as with the supervisor that is an agent with the task of evaluating the data as well as messages, and after judging the level of their importance it will start a respective action, or a whole sequence of actions, adequate to the situation appraised.

The implementation of the just described concept of the proposed solution is actually only in its early stages. However possible benefits of the proposed solution can be seen in:

- early warning possibilities;
- evacuation optimization;

- logistical planning;
- watershed manipulation optimization.

A number of other related ideas and solutions can be found also in [38], [39], [40], [41] or [42], among many others. Actually, this is a rather living and promising area of research.

5. Conclusions

In the paper, after an analysis of various recently used approaches, we presented a proposal of using multi-agent based and with ambient intelligence technologies enhanced application of an environmental wireless sensor network in the scope of water management. Except traditional centralized architecture of single reasoning agent (computing counterpart of human watershed manager), it is possible to use systems of reasoning agents, or to apply multi-agent simulations for verifying hypotheses about the next course of processes in the river basin. Partial implementations of multi-agent applications are expected to simplify communication with domain experts during the process of modelling their knowledge, identifying their needs and summarizing requirements on final application functioning. Further applications of the *Large-scale Ambient Intelligence* can be foreseen in various environmental areas as prevention of certain catastrophic situations, as water or air pollution, or in various agricultural fields.

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Proceedings of the 4th International Workshop on the Reliability of Intelligent Environments (WoRIE'15)

Editors

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Juan C. Augusto (Middlesex University, UK)

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Workshop Proceedings of the 11th International Conference on Intelligent Environments
D. Preuveneers (Ed.)

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Introduction to the Proceedings of WoRIE'15

This section contains the selected contributions for the *4th International Workshop on the Reliability of Intelligent Environments* (WoRIE'15), to be held within the *11th International Conference on Intelligent Environments* (IE'15) in Prague (Czech Republic) on 14 July 2015. The two previous editions of this workshop were held in Shanghai (China) and Guanajuato (Mexico), within IE'14 and IE'12 respectively, while the first one was held in Salamanca (Spain), within the *2nd International Symposium on Ambient Intelligence* (ISAmI'11). Our idea is to continue consolidating and strengthening this event with future editions, as a meeting point of researchers and practitioners of mainly two big communities: developers of intelligent environments and software engineers, with the aim of building solid bridges of collaboration between both communities, as well as discussing about their latest research works on the topics embraced by this workshop.

As we know, our society is currently facing important challenges related to the ageing of the population of developed countries and its effects on quality of life, health-care, people assistance, social inclusion, lifelong learning, etc. In all these areas, Intelligent Environments have a promising future, since these systems could be the solution to many of these problems that have a great impact in daily human life.

These Intelligent Environments are systems made up of a complex mixture of very diverse components, such as networks of sensors/actuators, communication protocols, middlewares, smart applications, location/positioning systems, to name only a few. Consequently, the area of Intelligent Environments is really a multidisciplinary domain, where researchers and practitioners of several technical fields (Ubiquitous/Pervasive Computing, Software Engineering, Human-Computer Interaction, Artificial Intelligence, …) have to collaborate and work together.

Accordingly, the development of this type of systems is a difficult and complex challenge, since networks are occasionally unstable, sensors are sometimes unreliable, unexpected events can happen at times, and users can put the system to the test in circumstances that were not initially foreseen. In addition, we have to take into account that many of these systems will have the tremendous responsibility for taking care mainly of vulnerable people, such as the elderly, chronic patients or people with disabilities, with the aim of supporting an independent living for them and increasing their quality of life.

For all this, we think it is essential to apply formal and/or semi-formal methods and techniques, mainly coming from Software Engineering, such as analysis, specification, modelling, verification, validation, simulation, among others, to analyse and establish the correctness of such systems, as well as to increase their reliability. Precisely these are the key topics and the main objective of this workshop. We also think that the collaboration of teams made up of researchers and practitioners coming from different disciplines should develop appropriate standards and specific methodologies to ensure we do our outmost to deliver safer and more reliable intelligent environments and to increase the user confidence in this type of systems.

In this edition, we will have a keynote entitled *Establishing Secure Intelligent Environments*, given by Wolfgang Apolinarski, to whom we thank for accepting our invitation to be our keynote speaker. Furthermore, the selected papers include both theoretical contents and empirical or real case studies to support the validity of their proposals, which are addressed to different scopes, but all of them have the clear intention of improving the reliability of the intelligent environments to which they are applied. These papers respectively present a self-adaptive architecture to address the availability of the services deployed in Dynamic Network Environments, a dynamic probabilistic risk assessment approach for Ambient Intelligence Healthcare Systems, a change impact analysis for context-aware applications in Intelligent Environments, and an introduction to Continuous Interaction Systems, which promote the simultaneous use of multiple devices and applications to complete tasks in a more effective, flexible and easy way.

Moreover, we are pleased to count on the newly inaugurated *Journal of Reliable Intelligent Environments* (JoRIE)[1]. This is a project closely related to our workshop; in fact, they share topics and objectives. To strengthen the link between both projects, we will determine the subjects to be addressed in a special issue of this journal during the celebration of this workshop edition.

We hope that all this will contribute to a successful workshop, where not only the presenters but also all the audience participate in mutually beneficial discussion. We sincerely trust that the workshop will be an appropriate forum where the sharing of knowledge and experiences about the reliability of intelligent environments and related systems (such as Pervasive/Ubiquitous Computing systems, Ambient Intelligence systems, Smart Environments, Multi-Agent Systems, etc.) promotes new advances in both research and development. We also expect that readers enjoy the papers included in these proceedings.

Finally, we wish to express our sincere thanks to IE'15 Workshops Chair, for his help and support, to WoRIE'15 Program Committee members, for their excellent work and invaluable support during the review process, and most importantly, to authors of the submitted papers, for their very interesting and high quality contributions, which have made possible to successfully organize the present edition of this workshop.

May 2015

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[1] http://www.springer.com/computer/hardware/journal/40860

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Establishing Secure Intelligent Environments

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Keynote

One of the main goals of intelligent environments is to create environments that provide users with seamless and distraction-free task support. Often, the task support is realized by so-called pervasive applications that are running on devices integrated into everyday objects. The set of everyday objects is not limited to devices that are already regarded as *smart* such as smart phones, but also include devices like refrigerators, coffee machines, light controls, power switches and other devices from everyday life. Furthermore, smart street lamps, smart ticketing and payment systems, smart homes and smart cars are already extending the size of such environments from small, local and isolated solutions to a ubiquitous, worldwide intelligent environment.

During the realization of this vision, we face several challenges. One of the challenges is the acquisition of context information through sensors that are often built into these smart devices. Additionally, the devices usually feature actuators that need to be configured such that they can be used to manipulate the physical world. Since the devices are highly integrated, they are also heterogeneous with regard to many aspects such as processor type, RAM size and power consumption. If we now consider additional factors such as mobility, it becomes clear that we are dealing with a highly dynamic environment. The configuration of such an environment and the introduction of common communication protocols or middlewares are therefore further challenges. Since it needs permanent adaptation to be able to cope with such an environment, manual adaptation by the user is not distraction-free nor feasible. As a consequence, another important challenge is the automated adaptation usually also performed by a middleware.

The security aspects of these challenges are often disregarded, since the first priority is usually to provide a working (technical) solution to each challenge. Nowadays, there already exist several approaches that solve (parts of) the problems of intelligent environments. Often, these approaches were created without security in mind and are thus inherently insecure. This is why we need to introduce security now, either by adapting existing approaches or by re-designing them. Establishing secure intelligent environments is a complex challenge that opens several questions, for example: Why do we trust a device? Why do we trust a sensor? How do we make sure the gathered context is really perceived by a sensor? Who is allowed to create a configuration for intelligent environments? Who is allowed to access data? How to detect a valid user?

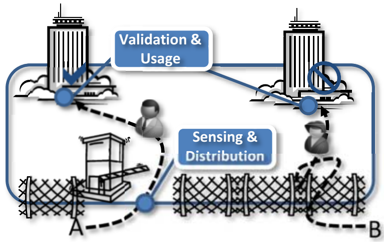

Figure 1. Secure Peer-based Context Distribution

(a) Shared key, at the event's wall (b) User-level key, at a participant's wall

Figure 2. Keys exchanged with PIKE in Facebook

At first, we show that security is an important aspect of automated configured intelligent environments and is usually a requirement for privacy. Imagine an adaptation decision that results in displaying a secret document on a public screen set up by a malicious user. The screen could easily be programmed to copy the document against the intents of the document authors. Similarly, while this would only result in intellectual property being stolen, devices like doors or smart cars without a proper security implementation will result in the theft of real goods. To overcome these issues, we present our approaches that are a first step towards secure intelligent environments.

The adaptation of intelligent environments depends on the detection of valid context information. We present a mechanism for secure context distribution [1] that allows a secure, distributed, peer-based verification of context, even when using resource-constrained devices such as sensors. Additionally, it does not require that all devices, which form one infrastructure, are part of one network. Instead, sensors can sense context independently and issue a context token that can later be validated (e.g., to open a door at an office building as shown in Figure 1). The provided context information can then be used to create a secure role assignment [2], which allows the secure, automated adaptation of intelligent environments. Here, trust and security are provided by using a simple but effective trust system with certificate hierarchies, allowing to establish an Internet-grade security level. As we elaborated further about trust, we came to the conclusion that users are already defining trust between each other in online collaboration platforms such as Google Calendar or Facebook. We therefore present our approach PIKE [3] that exchanges secure keys which are later used for secure, privacy-preserving communication between users, transferring trust relationships from the virtual to the real world. While PIKE can be used to establish mutual keys, it can also be used to identify participants at a shared event such as a conference or party. Examples of a PIKE-initiated key exchange can be seen in Figure 2.

Although the feedback we get from these first approaches are promising, there is still a lot of work waiting. During the talk, we outline past and current work and show gaps that need further attention. In the end, we will have a clearer view on what is needed to really establish secure intelligent environments.

Acknowledgments

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An Approach Addressing Service Availability in Mobile Environments

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Abstract. Mobile Cloud Computing paradigm has arisen as a major proposal to address collaboration support in working environments. Particularly, this paradigm has proven to be useful in emergency scenarios, education or tourism. However, these environments are commonly based on dynamic network topologies, which imply unstable connections (disconnections and network partitions). In consequence, the availability of the services can be compromised. Therefore, approaches based on the Service Oriented Architecture (SOA) are insufficient and they must be complemented with techniques and methods of Autonomic Computing, in order to ensure the quality attributes of the system against context changes. In this work, a self-adaptive architecture is proposed in order to address the availability of the services deployed in dynamic network environments. This architecture has been designed to provide a common basis for collaborative mobile systems. The architecture follows a component-based design, and it provides a distributed approach to support the dynamic replication and deployment of services. Further, an example scenario based on a real Mobile Forensic Workspace is described to show the applicability of the proposal.

Keywords. Context-awareness, autonomic computing, dynamic network topologies, mobile environments, Service Oriented Architecture (SOA)

1. Introduction

The Service Oriented Architecture (SOA) proposes a modular distribution of the functionalities of a system through services [1]. It provides the foundations to build an interoperable and scalable system thanks to the use of standard protocols and service composition. However, SOA itself is not sufficient to be able to operate in dynamic network environments [2], such as *Mobile Cloud Computing* [3]. Such environments pose new features, and, if they are not correctly addressed, they may have a significant impact on the quality attributes of the services [4]:

- *Energy constrained.* The energy supply is one of the main weaknesses of the mobile devices. Some approaches to guarantee certain quality attributes in this kind of system are often in conflict with the energy-aware performance. For instance, the availability of a service is directly proportional to its number of replicas. However, an intensive replication will require intensive energy consumption. Therefore, it is necessary to provide an energy-aware architecture that balances the performance of the system with efficient energy consumption.
- *Dynamic network topologies.* The topology of a mobile network changes frequently and unpredictably, owing to the mobility of the nodes that makes up the network. Further, the nodes may be switched off or may be disconnected (temporarily or permanently). Since these networks are typically multi-hop, this usually leads to link failures, route changes or even network partitions.
- *Dynamic demand patterns.* The set of clients of a service is increased/decreased over time. Additionally, the location of these clients may change. These circumstances can result in bottlenecks and an inefficient use of the available bandwidth.
- *Heterogeneity.* A wide range of computer-based subsystems (laptops, smartphones, wearable devices, sensor networks, etc.) are being used and integrated for building current advanced systems. The performance, average reliability, available technologies (such as GPS, NFC or Bluetooth), and capabilities of each node may vary.

These features pose a challenge for engineers and developers of software architectures, who must make suitable architectural design decisions to address them correctly. For instance, the reliability and performance of distributed applications are critically conditioned by the placement of the services in the distributed system [5]. Nevertheless, the conditions of energy, topology, demand patterns, and heterogeneity vary over time, i.e., they are dynamic features. Therefore, in order to address the availability of services, some decisions and associated techniques, such as deployment, replication, and migration of services should be applied in run-time.

As a result, self-adaptive architectures have been gaining importance in the research community [6]. A self-adaptive architecture has been complemented with self-* features (i.e., self-healing, self-configuration, self-optimization and self-protection [7]), and it has the capability of reducing the impact of context changes in the quality attributes of the system. This kind of architectures has a substantial potential in different application domains. For instance, in the forensic domain can be found different scenarios: natural disasters, accidents, terrorist attacks, etc., where the common network infrastructures are not available and the forensic experts need apply action protocols to support victim identification. In this context, the *Mobile Forensic Workspace* [8] intends to provide support to forensic experts in data collection and sharing using a mobile system. However, the features previously exposed may negatively affect the availability of the services, and thus hampering to achieve the ultimate goal of forensic experts.

This paper introduces a self-adaptive architecture, which aims to guarantee the availability of services in dynamic environments. This architecture has been designed to provide a common basis for mobile collaborative systems. It is based on previous findings [9], which have been validated through a preliminary evaluation on the Network Simulator 3[1]. The results obtained have allowed ratify some of the concepts previously pro-

[1]https://www.nsnam.org/.

posed and introduce new findings in the proposed software architecture. These findings are introduced at three different levels: (1) in the design of the architecture, the components of each subsystem are identified and defined; (2) in the communication between the components, the events that trigger the adaptation are described; and (3) in the management of the network topology, a new method to identify the position of the nodes within the network are proposed. The architecture follows a component-based design, and provides three main subsystems: the Monitor Subsystem, which is responsible for monitoring events in the context of the device that can affect to the availability of a service; the Context Manager Subsystem, which store information about the own device and other nodes of the network; and the Replica Manager Subsystem, which carries out the dynamic replication and deployment of services through a fully distributed approach.

The rest of this paper is organized as follows. Section 2 presents a study of the main issues that have been addressed in the literature in order to improve the availability of services in dynamic environments. Section 3 introduces a self-adaptive software architecture to support the dynamic replication and deployment of services. In Section 4, an example based on the Mobile Forensic Workspace is described to show how the approach helps to improve the availability of the services deployed in that system. Section 5 provides a brief discussion about the proposal. Finally, Section 6 draws some conclusions and outlines the plans for future research.

2. Related Work

In 2003, IBM proposed a reference model for autonomic control loops, called MAPE-K loop (Monitor, Analyze, Plan, Execute, Knowledge) [10]. This model has been widely used as base to define autonomic systems, including systems that require dynamic replication and deployment of services. Regarding this kind of systems, two steps in the adaptation loop have a major impact on their performance: when replicate and where place the replica.

There exist different events that can trigger the creation, migration or deletion of replicas, for example, the battery of the host device is running out, or the device switches off, the demand for the service increases, etc. Between these events, the prediction of a network partition can be highlighted. A network partition can affect to the availability of a service and consistency of the shared information [11]. The fact of predicting a partition allows taking the necessary actions to ensure the consistency of the shared information and the availability of the service, while the connection is still available. Chandrakala et al. [12] propose a predictive algorithm based on the position of the nodes, their speed travel and range. When a partition is predicted, the node where the replica will be placed is chosen by taking into account the distance from the source node (i.e., the node that have a copy of the service and from where the replica will be created and sent), its battery and its storage capacity. In [13], TORA routing protocol is used in combination with an estimation of the residual link lifetime of wireless links. When a device predicts a partition, this device will host a replica of the service, regardless of its characteristics.

In collaborative systems, the partition prediction algorithms may be relegated to second place. In this kind of systems [14,15], the set of services is well-known in deployment time, thus an approach based on hibernation [16,17] in which the replicas of the services can be deployed in each device is feasible. On the one hand, the advantages of this approach are as follows: better response times; the service does not have to be sent in real time, hence, there is a more efficient bandwidth and energy use; and also the system is less dependent on the available technology, because the requirements on bandwidth are less stringent. On the other hand, the system will be less flexible, since new services cannot be introduced in the network at run-time.

Moreover, in large scale systems [2] the scalability is a main objective for software architects. Device clustering methods are applied in order to turn a distributed network into a set of interconnected local clusters that can be dealt with individually like a centralized network. In this way the management of the network is simplified, achieving scalability under a "divide and rule" approach. Dustdar et al. [16] create device clusters on the basis of the distance between mobile devices. However, in [18,19] is shown that the travel speed of devices is a better measure to create clusters of mobile devices. In [19], service replicas will be created when too many requests are made to a service from an external group. Hence, this proposal intends to achieve the property of localized scalability [20], reducing the communications between distant entities, in order to safeguard the bandwidth and the energy of the system. In [16,19], the device that will host the new replica is chosen by considering its computational capabilities (battery, CPU, memory, etc.), without taking into consideration either its current workload or the network topology. Consequently, the resources of the host device can be quickly depleted.

Finally, Hamdy et al. [17] propose a replication protocol based on the interest of devices in the use of the service. When an application needs to access a service and there is not a replica of that service in its neighbourhood, a replica of the service will be created and deployed in the same device in which the application is hosted.

Generally, these are ad-hoc solutions developed for specific application domains, and they are based on an implicit, and often restricted, context model. The definition and use of an explicit context model can facilitate the adaptability and reusability of the proposal. The possibility of extending the model according to the particular requirements of a scenario would provide a more effective solution in terms of performance to such scenario.

3. A Self-Adaptive Software Architecture

The proposed software architecture has two main objectives: (1) provide a reusable and adaptable base for collaborative support systems, (2) enhance the availability of services in dynamic environments through an adaptive replication and deployment approach.

The architecture has been initially designed to support medium size work groups, which allows a hibernation approach. Thus, it follows a logic approach to the replication and deployment of services. Further, in order to provide a fully distributed approach, the different nodes of the network must coordinate themselves at run-time to decide which of them will be the active replica.

In order to provide an adaptable and reusable software architecture a component-based design has been followed [21]. The architecture can be divided into five main subsystems (Figure 1): the *Monitor Subsystem*, which is responsible for monitoring events in the context that can affect the availability of a service; the *Context Manager Subsystem*, which processes and stores that information; such information will be used by the *Replica Manager Subsystem*, which encapsulates the adaptation logic regarding the repli-

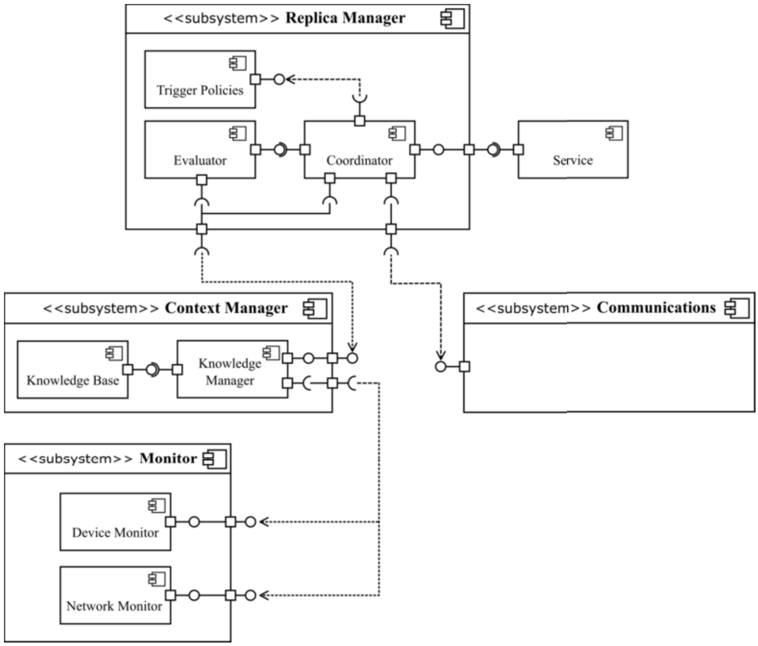

Figure 1. Subsystems for the self-adaptive software architecture approach.

cation and deployment of the service replicas; the *Communications Subsystem*, which allows the *Replica Manager Subsystem* to communicate with other nodes of the network; and finally the *Service* itself, which will be a passive or active replica according to the decision of the *Replica Manager Subsystem*. These subsystems are described in depth in the following sections.

3.1. Monitor Subsystem

The *Monitor Subsystem* encompasses a set of monitoring components, which are sensing the context of the device in order to detect potential events that could affect the availability of a service. To monitor the context is a costly operation in terms of energy and bandwidth. Nevertheless, the performance and response time of the adaptation system depend on the precision of this action. Therefore, to provide an appropriate balance between the cost and the precision, through the sampling frequency, is required.

In the proposed architecture, device and network capabilities are monitored. The information about the device capabilities is local information that usually can be obtained easily. However, a dynamic network topology requires a continuous monitoring because of constant changes that occur. Further, the cost increases exponentially with each hop in the network. Accordingly, the scope of the monitoring will be limited.

There are different approaches to monitoring a network topology. The majority of those approaches are based on the position of the nodes and their travel speed. This requires using the GPS system and exchange such information constantly, which have a heavy impact on the energy of the device. As a more efficient alternative, in this work is proposed to use the information provided by the routing protocol, such as *Optimized Link State Routing Protocol* (OLSR) [22], to estimate the network topology.

The routing protocol builds and provides the routing tables with information about the reachable nodes, and for each node the gateway and the number of hops. Through the direct connections of a node, its position within the network topology can be approximated. For instance, a node with four direct connections will be in a more centric position within the node group, and therefore will be a more stable node than other ones with only one direct connection. This approach is more efficient than GPS-based ones, but less precise. Still, the component-based design allows exchange the *Network Monitor* component, adapting the system at run-time according to current conditions [23].

3.2. Context Manager Subsystem

The *Context Manager Subsystem* is responsible for processing and storing the information received from the monitors of the device. This information will be used by the *Replica Manager Subsystem* in order to adjust the deployment of the services according to the changes produced in the execution context. This information will be provided in two different ways: (1) under a Publish-Subscribe paradigm, where the *Context Manager* notifies, through a push-based communication model, the *Replica Manager* about events of its interest. For instance, an event will report the battery level every time that the battery decreases a 5%, or an event will be published when the active replica is not reachable; and (2) under a Request-Response paradigm, when, for example, the *Replica Manager* requests the *Context Manager* about information to evaluate the adequacy of the node. The combination of both paradigms is usually known as SOA 2.0 [24,25] (a.k.a. advanced SOA), in which services are not just passive entities, but also they are able to receive and generate events proactively.

Although, all the nodes share the same data model, the information stored by the *Context Manager Subsystem* is mainly local to device (battery consumption, number of direct connections to other devices, remaining storage capacity, etc.) and only the evaluation of the node is shared with the rest of the system, in order to reduce the bandwidth consumption. Hence, each node maintains a list with the evaluation of each reachable node in the network.

The importance of the different context aspects that may influence the dynamic replication and deployment of services will depend on the particular application domain. However, the following context aspects have been identified as relevant to provide a solution, regardless application domain (Figure 2): device features (e.g., battery, memory, processing capacity, etc.), network topology (e.g., client-service distance) and service requirements, i.e., how the device features match the requirements of each specific service.

- *Device features.* A device feature can be a simple feature, such memory or storage, or a compound feature, such remaining battery. That is, a compound feature is derived from two or more simple features. For example, remaining battery could be calculated from screen brightness, CPU usage, phone signal strength, and other features. It is important to take into consideration the device features in order to choose the devices with best performance to host services. Also, the current usage of these resources must be taken into consideration to deploy a service replica (remaining battery, CPU or memory, among others).
- *Service requirements.* Although there is cross-cutting information that affects in a similar way the deployment of all services of the system, such as the device battery or client-server distance, there is other information that affects in a greater or

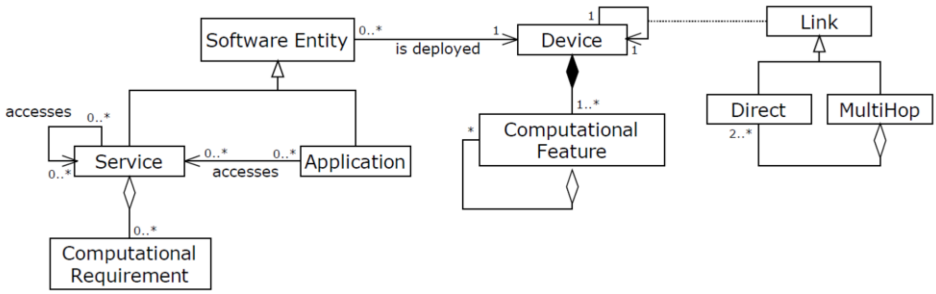

Figure 2. A context model for self-adaptive service replication and deployment in dynamic environments.

lesser measure in relation to the service requirements. For example, one service could need high processing power while other could need high storage capacities. For this reason the services must specify theirs *Computational Requirements* independently [14]. The service developer must indicate what features must be provided by the devices in which the service could be deployed, through a set of condition statements (e.g., “free storage space equal or greater than 1GB”). This would allow the system to distribute the workload among the devices of the network, providing the appropriate deployment of the services. Moreover the number of clients (i.e., applications and other services), dependencies between services (i.e., regarding service composition) and number of replicas of the service, are also interesting context information to provide an efficient service deployment solution.

- *Network topology*. Each device has two kinds of *Links*: *Direct links* (one-hop) and *Multihop links*. Each *Multihop link* is made up of two or more direct links between devices. In order to simplify the management of the network topology, the model only considers the best path between two devices, but it is independent of its calculation (fewest hops, higher bandwidth, best stability, etc.).

3.3. Replica Manager Subsystem

The *Replica Manager Subsystem* encapsulates the adaptation logic regarding the replication and deployment of the service replicas. In order to provide a fully distributed solution, each service replica has a *Replica Manager Subsystem*. It consists of three main components:

- *Evaluator*. This component implements the evaluation function that will be used by the Coordinator component to evaluate the suitability of the node to host a specific service. This evaluation is based on the information provided by the Context Manager, and the weight of each context feature will depend on the application domain and the specific situation. For instance, if the battery of a device is running low, the evaluation function can dynamically change to assign more priority to this context feature. Therefore, a developer could define different Evaluator components to address different situations occurring in a specific application domain.

- *Trigger Policies.* Through this component, the developer can adapt the system to the particular requirements of a specific application domain. In it, through a rule-based system are described the trigger policies, which are related with the reception of events through the Context Manager. This information will help the Coordinator component to know when adapt the deployment of the service could be needed. For example, by way of these rules can be indicated: *replicate* a service when the resources of the current host device are running out (e.g., the battery power is below 20%), the topology of the network changes (e.g., a partition is predicted, or the active replica is not already reachable), or new clients appear; *migrate* a replica when the distribution of the clients changes, or a better device to host the replica is discovered; or *hibernate* a replica when the number of clients is reduced. As with the Evaluator component, different trigger policies could be necessary to address different situations in the same system.
- *Coordinator.* When, through trigger policies, it is detected a change in the context that could affect the quality attributes of the service, the Coordinator component is responsible for coming to an agreement with the rest of the replicas deployed in the system. The objective of this coordination is to know if a better deployment exists and, if so, to establish what will the active replica. As the proposed architecture follows a distributed approach, a consensus system is followed. Each Coordinator evaluates itself and sends this evaluation to the other reachable nodes. At the same time, it receives the evaluation from the other nodes. Using this information, each node gives its vote to the node that it considers most appropriate to host the replica, and the most voted node will host the replica. This procedure provides robustness against message loss, owing to it is not necessary to the proper functioning that all nodes have an identical list of evaluations, and the node election process only requires that it receives half plus one of the votes. The adaptation process can be initiated by any Coordinator as they have local information that is not accessible by the rest. Once that one Coordinator requires for a check of the current deployment of the service, the rest of the Coordinators follow the initiative and start the vote process.

4. Example

The *Mobile Forensic Workspace* [8], which allows forensic experts to exchange information in real-time for data sharing purposes in case of natural disasters, accidents, terrorist attacks, etc., is helpful to show the need and usefulness of the proposed architecture. The Figure 3 depicts a hypothetical scenario where three members of a forensic team are gathering preliminary evidences of two victims. In the scenario two kinds of devices can be found: (1) a laptop deployed statically in a police car; and (2) three mobile devices (one for each team member). Additionally, different services can be found (communication, image repository, victim's information repository, etc.). In the case of Image Repository service, each forensic expert can take several pictures of an evidence with his mobile device; different forensic experts can take photos for the same evidence; or the same forensic expert can take photos for evidences that belong to different victims. Moreover, the forensic experts can add annotations to these pictures, which can be related with other pictures. Therefore, the Image Repository service must keep an ordered and consistent

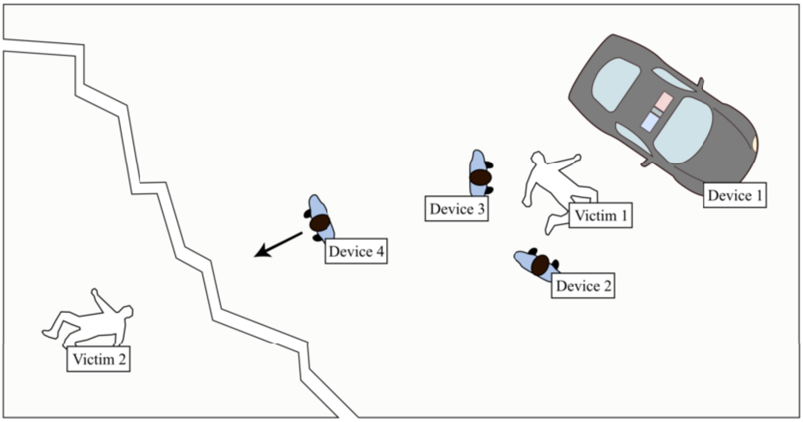

Figure 3. A hypothetical scenario within the Mobile Forensic Workspace case study.

set of this information, and at the same time it must provide high availability, to allow forensic experts to access and share pictures about the evidences found.

In this scenario, the proposed self-adaptive architecture can be useful to improve the availability of the Image Repository service. This is highlighted in the following situations:

1. Initially, all forensic experts are near the Victim 1. All the mobile devices are connected with the laptop located in the police car. Therefore, the active service replica (copy-primary protocol) is the one deployed in the laptop (*Device 1* in the Figure 3), as it presents better computational features.
2. The forensic expert of the Device 4 will move to the area where the Victim 2 is located. This area is out of the laptop coverage. The Monitor subsystem detects this situation, by way of a disconnection prediction method or because the active replica is not already reachable. Thus, it publishes the proper event that is received by the Replica Manager, through the Context Manager. The Replica Manager can manage this situation by means of its trigger policies and it starts the adaptation process. As the only replica available is itself, it will turn to active. At this point, the network is partitioned into two groups: (1) the Devices 1, 2 and 3, where the Device 1 hosts the active replica; and (2) the Device 4, that provides service to itself.
3. Later, the forensic experts of the Devices 2 and 3 move to the victim two area. The Context Manager of the Device 4 has been publishing events related with the battery power every time that it has decreased a 5%. At a given time, this event reports that the battery is under the 25%, therefore, the rule that reflect this situation in the trigger policies is activated. The Coordinator will search a better node in order to host a replica of the service. Following a distributed process, each replica will evaluate its adequacy to host the active replica, it will send this evaluation to their neighbours, and once that obtains the score list of the nodes, it will emit a vote for the best ranked node. The node with the half plus one votes will provide an active replica. Moreover, the active replica deployed in the laptop (Device 1 in the Figure 3) will have no clients, in this device there are no

applications that require the service. Therefore the Coordinator will hibernate the replica in order to save resources.

5. Discussion

The proposed architecture provides a base to support the dynamic deployment of services in dynamic network environments. This architecture helps to address the availability of the services for this kind of environments, and with it, the applicability of SOA-based approaches. Moreover, the management of the self-adaptation is carried out through a fully distributed approach. This provides robustness to the system against node disconnections or failures, since no node is indispensable. Besides, the consensus-based approach to elect the hosting node provides robustness against message loss.

Furthermore, together with the architecture, a context model is provided. It allows adapt the proposal to the specific requirements of an application domain. Additionally, the component-based design allows adapt dynamically the behaviour of the architecture. Generally, the proposals presented to improve the quality attributes of services in dynamic environments (see Section 2) are ad-hoc solutions developed for specific scenarios, and they are based on an implicit, and often restricted, context model. The presence of an explicit context model allows developers to customize or reuse the proposal.

The current proposal is designed to support medium or small size work groups. It is designed on the basis of a copy-primary scheme [26] in physical partitions. Nevertheless, in large scale networks this replication scheme could be inefficient. In large groups the active replica could easily become in a bottleneck, and therefore, a physical partition could need more than one active service replica. The creation of logical partitions provides scalability to system and it facilitates the management of a large scale network. This can be done through clustering techniques, and will be transparent for the adaptation system, as the adaptation logic to manage physical network partitions is transferable to manage logical partitions.

Finally, the proposed architecture follows a hibernation-based deployment approach. The set of the services is well-known at design time and their replicas are deployed in the devices before run-time. Such approach reduces the flexibility of the systems, as it is not possible to deploy a new service or introduce new devices at run-time. However, it can reduce the requirements about bandwidth and improve the response time of the adaptation process. Thus, the current architecture follows a logic approach to the replication and deployment of services. However, a hybrid approach could be provided, where well-known set of devices could be deployed in deploy time and also could be possible to add and deploy new services at run-time. This is a technical question, since the current implementation of the adaptation logic is transferable between both approaches, and the code mobility [27] can be implemented in a transparent way for the current adaptation process.

6. Conclusions and Future Work

In this work, a self-adaptive architecture has been presented. The architecture has two main objectives: (1) provide a reusable and adaptable base for collaborative support systems; and (2) try to enhance the availability of services in dynamic environments through an adaptive replication and deployment approach. The management of the self-adaptation is carried out through a fully distributed approach, providing robustness to the system. This approach takes into account crosscutting context features, such as the network topology or the battery device. Moreover, the Mobile Forensic Workspace has been described. It illustrates the need and usefulness of the proposed self-adaptive software architecture.

At present time, a study of the proposed system in a network simulator is under development. This study will allow investigate the performance of the system regarding different configuration parameters (such as monitoring intervals, routing protocols, replication strategies, etc.), and to empirically compare the behaviour and the performance to other approaches. Preliminary results show a great increment in the availability of the services, with a uniform consumption of the battery of the devices of the network, and distributing uniformly the workload between the different nodes of the network. As future work, the self-adaptive architecture will be extended with clustering techniques, in order to address scalability in an integrated way.

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A Preliminary Study of a Probabilistic Risk-based Approach for Ambient Intelligence Healthcare Systems

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Abstract. The Ambient Intelligence (AmI) paradigm applied to the healthcare sector is a promising solution to develop software-based systems capable of supporting medical procedures and activities carried out in a close, high-regulated, and complex healthcare environment. An AmI Healthcare System (AmI-HS) which may impact on the health and life of its users (i.e. doctors, caregivers, patients, etc.) is considered as a Medical Device (MDs), and thus subject to pass through a cumbersome risk-based regulatory process which evaluates and certifies the system safety before it is put on the market. Thus, a human-centred risk analysis is of paramount importance to establish the safety level of an AmI-HS.

In this paper, we propose a dynamic probabilistic risk assessment (DPRA) approach for AmI-HS which allows the quantitative assessment of risk in different hazard scenarios in order both to support the design and development of AmI-HSs and to provide those objective evidences needed during the regulatory process. In addition, to support our risk-based methodology we define a probabilistic risk model (PRM), based on an extension of a Markov Decision Process (MDP), capable of taking into account two main peculiarities of AmI-HSs: context-awareness and personalisation. Some preliminary results show the feasibility of our approach and the capability of our model to assess risk of context-aware hazard scenarios.

Keywords. Probabilistic Risk Assessment, Probabilistic Model Checking, Markov Decision Processes, Safety, Ambient Intelligence

1. Introduction

The pervasiveness of sensors and mobile technologies such as smartphones, personal digital assistants, tablets, etc in our daily life along with the widespread use of digital networks as the backbone by which such devices can exchange data has been allowing the advancement and promotion of software-based components everywhere all around people. Ambient Intelligence (AmI) systems exploit such technologies in order to sense the context, gather situational data, elaborate information, and support human activities in the environment in which they are carried out.

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For a wider comprehension of AmI concepts and applications we refer to [1,2,3]. Instead, in this paper we narrow down our attention to AmI Healthcare Systems (AmI-HS) [4] which distinguishably present three features. First of all, the human factor plays a fundamental role because of both the wide interaction between humans and digital devices and the unique capabilities of humans in doing activities not performable by any autonomous computational system, or for which humans are considered more reliable (e.g. medical diagnosis). Secondly, AmI-HSs are distributed systems which connect and use environmental sensors and medical devices (e.g. body sensors) with the ultimate purpose of simultaneously managing and controlling both medical activities and patients' physiology in a predefined environment such as hospitals, healthcare departments, nursing homes, etc. Finally, as such, AmI-HSs themselves are considered as medical devices since, according to the article 1,(2)a of the European Medical Device Directive [5], a medical device (MD) is any apparatus, along with the software with which it is equipped, used to support human activities for the purpose of diagnosis, prevention, monitoring, treatment of disease, compensation for an injury, investigation of a physiological process.

All these features heavily affect the design and development of AmI-HS and have to be taken into account from the outset. Furthermore, the last point constraints manufacturers to follow some standards for the development of MDs (e.g. IEC 62304) since such products are subject to pass through a regulatory process that certifies their quality based on the safety of users. Generally speaking, medical regulations define a risk-based certification process whose aim is to collect, evaluate and check the objective evidences useful to prove that the MD under scrutiny either prevents or appropriately mitigates all the risks users may face by using it. Neither regulations nor standards define how to produce the objective evidences specific for a particular MD.

In this paper we want to present a quantitative methodology whose aim is to fill this gap. In detail, we define a probabilistic risk model (PRM), based on Markov Decision Process (MDP), for the purpose of performing risk assessment appropriately to AmI-HSs. Particularly, our risk model considers two important characteristics of AmI-HSs, i.e. context awareness and personalisation. The former refers to the contextual and situational information an AmI-HS needs for supporting users activities. The latter concerns the presence of doctors, caregivers, nurses, patients, each one with their own roles and capabilities which have to be taken into account to evaluate and manage risks. We will apply our approach to a case study of an AmI-HS for a Nuclear Medicine department in order to show the effectiveness of the methodology proposed.

To sum up, the main contributions of this work are the following:

- the definition of a quantitative risk analysis methodology, based on probabilistic model checking (PMC) techniques, to support the AmI-HS quality assessment for the purpose of user safety.
- the definition of a probabilistic risk model to assess risk of context-aware hazard scenarios.

The remainder of the paper is structured as follows. Section 2 introduces (Subsection 2.1) the case study we use as a reference throughout the paper, then (Subsection 3) it is presented the methodology we propose. Section 3 reports the definition of the probabilistic risk model we have conceived specifically for AmI-HS. In Section 4 the case study is recalled to show an application of our methodology and its feasibility. Section 5 presents a brief description of related work. Finally, Section 6 concludes the paper and discusses future directions.

2. The Dynamic Probabilistic Risk Assessment Methodology

2.1. Case Study

The case study we present is taken by [3]. It is an application of Ambient Intelligence to a department of Nuclear Medicine (AmI-NM). Within the NM department the patients who need to be examined have to take specific radiopharmaceutical, i.e. a radioactive agent, according to the diagnostic imaging examinations to be performed (e.g., blood volume study, bone scan, brain scan, etc.). Once such agent is taken, the patients emit radiation and have to stay in a specific room to wait for until the radioactive agent passes through, or is taken up by, the organs to be diagnosed. The time the patients have to wait depends on the kind of examination to be performed and the time that the radiopharmaceutical takes to propagate within the body so as to reach the right radioactive level. In fact, examinations can be carried out only if the radiation level is within a certain range. After the patient's examination, he/she goes to the waiting room until the level of radiation he/she is emitting falls below a specific threshold and so becomes harmless.

Currently, the patients are accompanied by nurses when moving within the department. The goal of the AmI-NM is to have an automatic system that would guide patients within the department and so free specialised medical staff. Thus, the system has to ensure that patients strictly follow the medical procedure. For this reason, it has to be able to track patients movements in the department, and to monitor their heart rate as well as their radioactive level so as to promptly send alarms to caregivers if something wrong happens (e.g. possible undesired effects due to the injection, the stay of a patient in an area either forbidden or radioactive, the change of the diagnostic procedure because of some unforeseen circumstances).

For our purpose we abstract away from a specific NM department and then we consider it as being constituted of four locations:

1. the Acceptance Room (AR), which is the room where the patients are accepted into the department to wait for their injection.
2. the Injection Room (IR), which is the room where the patients receive the injection.
3. the Waiting Room (WR), which is the room where the patients wait for the examination after having been injected and until the radiation level reaches the correct range.
4. the Diagnostic Room (DR), which is the room where examinations are performed.

The last three rooms are equipped with short-range RFID readers so that patients can be tracked by the system. Within the AR, an operator registers the patients and equips them with an RFID tag, an ECG sensor, a radiation dosimeter, and a Personal Digital Assistant (PDA). After the registration phase, the system receives data streams from these sensors in such a way it can monitors, controls, and manages patient's activities and environmental conditions.

When the patient moves into an area, the system determines the presence of a new RFID tag in a physical location by means of the RFID reader. For instance, an event like Tag = 127; RFID Reader = 2 is produced and translated into semantic information (e.g., Patient = Massimo Rossi; Location = Injection Room). For the sake of brevity we refer readers to [3] for further information about the system design and architecture.

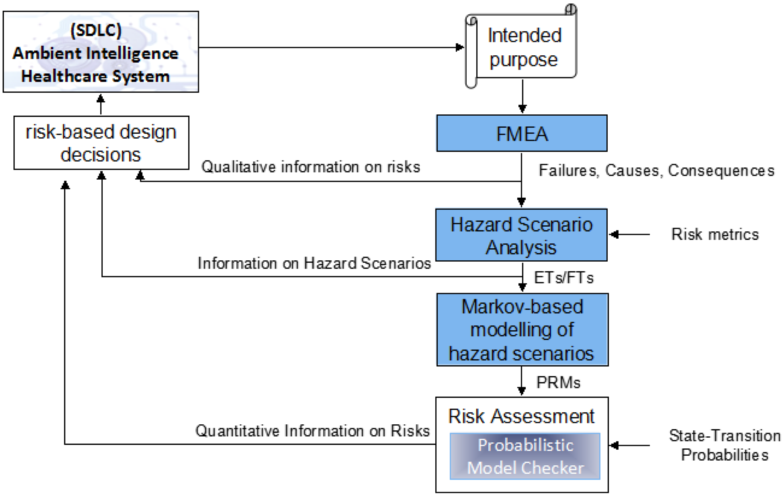

Figure 1. Dynamic Probabilistic Risk Assessment methodology based on Markov Chain Model Checking

2.2. *Risk-based Approach*

Risk Analysis (RA) and Management is of utmost importance for the MD software industry since it is the means by which assuring that unacceptable risks are avoided and acceptable ones are mitigated for the safety of both patients and healthcare operators.

For the nature of AmI-HSs, the state of the art RA method known as Failure Mode and Effects Analysis (FMEA) [6] is limited due to its subjective and semi-quantitative estimation of risk severity and probability ranking, but far more because it does not take into account the dynamics through which a negative consequence results from a hazard event (failure).

The methodology we have conceived is based on the Dynamic Probabilistic Risk Assessment (DPRA) [7] approach which overcomes the aforementioned issues related to a traditional static method (see [8]). Widespread DPRA formalisms such as Event-Tree (ET) [9] and Fault-Tree (FT) [10] are particular useful to represent and analyse hazard scenarios of systems with the following characteristics:

- The system's responses and/or results are influenced by the dynamics of phenomena
- The process dynamics affect the behaviour of hardware/software component failure, the human operator actions, and the human-machine interactions.
- Some failure modes are related to the process dynamics.

To address the complexity of AmI-HS and to take into account both the human factor and the context awareness, the ET/FT solution is limiting because the event order is fixed for a hazard scenario, the temporal aspect is not considered, and it is not possible to account for context-dependent events.

To account for such aspect we define (see Section 3) a Markov-based probabilistic risk model (PRM) as a formal model to represent hazard scenarios. A probabilistic model checking (PMC) technique [11] is then exploited as an automatic, efficient, and powerful solution to perform both qualitative and quantitative risk assessment.

The methodology we propose is illustrated in Fig. 1. It still takes advantage of both FMEA and ET/FT techniques to, respectively, obtain risk information with respect to the static elements designed into the AmI-HS (through qualitative and/or semi-quantitative analysis) and also the dynamics of hazard scenarios.

Particularly, during the Software Development Life Cycle (SDLC) of an AmI-HS from the intended purpose document, an FMEA is carried out to identify hazards, their causes, and consequences, as well as to prioritise hazards on the basis of their effects on the system users. For those hazards that needs to be examined in more detail, the “Hazard Scenario Analysis” phase allows the disclosure of the actual dynamics which relate causes and effects. The results of such a phase is a set of ETs/FTs describing the hazard scenarios of interest. The last two phases are the real innovation of this methodology. The input of the ”Markov-based modelling” phase is the output of the previous phase, i.e. the set of ETs/FTs. These serve in supporting the definition of the PRMs representing the scenarios which must be analysed.

Finally, to perform risk assessment of hazard scenarios, the PRMs are implemented and analysed by using the probabilistic model checking tool PRISM [12]. Specifically, the PRMs can be described in a parameterised way with respect to transition probabilities. In this way, by tuning the model parameters, i.e. the transition probabilities, it is possible to quantify the total risk for different realisations of the same scenario so to both better support the risk analysis process and take into account the unavoidable uncertainties that experts’ estimations or real measurements of probabilities bring in the assessment phase. Choosing or estimating transition probabilities is not within the scope of this paper, but references (such as [13,14]) are given in the literature .

3. Probabilistic Risk Model

In the following we present the probabilistic risk model (PRM) conceived within the methodology we proposed in Section 2 As a starting point we have taken the formal definition of generic AmI systems given in [2]. In that work, an AmI system is defined as being composed of three main items: a real environment, and a set of interaction constraints, a set of occupants, e.g. humans, pets, robots, etc.

Our insight for defining a PRM derives from focusing on the following important aspects related to risk in the fields of both Medical Devices and AmI:

- take into account those interaction constraints in which hazards for intended users can be present
- formalise those interaction rules for which the AmI system decision-making process for supporting human activities may experience failures
- consider each category of human and non-human occupants that are involved in hazard scenarios
- model the physical spaces within the whole environment - hereafter we call them contexts, in which events of interest for evaluating hazard situations may be generated
- represent only those human actions that contribute in some way to hazard situations

For the last point it is worth emphasising that the set of human actions vary according to the type of people as well as to the space in which occupants are immersed. For instance, as we will see in the example presented in Section 4, in our reference case study patients or caregivers act differently if they are in the injection room compared with the diagnostic room.

We thus formally define a PRM for an AmI-HS as follows:

$$PRM = \langle C, O, \{MC_i\} \rangle$$

where:

C : is the state space, i.e. the set of contexts making up the environment in which the AmI-HS gives support to human activities. To the purpose of analysing hazard scenarios, we augment such space with two virtual contexts "Not Allowable" and "Unknown" which aggregate, respectively, all the other contexts in which an occupant should not be and the possibility that the system fails to determine the context in which an occupant is.

O : is the set of occupants[2]denoted by $O = \{1, \ldots, n\}$

MC_i : is what we define a Context Markov Decision Process (Ctx-MDP) for each occupant $i \in O$, i.e. an MDP which allows us to model both the behavioural movements and the possible sequences of actions performed across and within contexts by an occupant

In detail we define a Ctx-MDP MC_i for an occupant $i \in O$ as an extension of a MDP in the following way:

$$MC_i = \langle \{m_c\}, Act, P, R \rangle$$

in which:

$\{m_c\}$: is the MDP modelling the stochastic and non-deterministic behaviour of the occupant i within the context $c \in C$.

Act : is the set of actions, composed of $\{$`move-in, move-out`$\}$, which allow modelling of when an occupant comes into or moves out of a context.

P : is the probability distribution that captures the stochastic aspect of an agent's behaviour. It is defined upon the transition function $T : C \times Act \times C \to [0, 1]$.

R : is the reward function $R : C \times Act \to \mathbb{R}$ which, given a context $c \in C$ and an action $a \in Act$, specifies a real number. In particular, we assume positive numbers are rewards, whereas negative ones are costs.

Intuitively, a Ctx-MDP is an MDP which models the stochastic behavioural movements of an occupant within the environment, partitioned in the set of contexts C. Moreover, for each $c \in C$, m_c is the MDP which represents the behaviour an occupant exhibits when he/she is within that context.

[2]without loss of generality, an occupant $i \in O$ can represent either a single person or a category of people, e.g. patients having the same pathology

Failure	Cause	Consequence
Contrast agent has passed its peak in the patient's body	accelerated heart rate	Patient fails to follow the examination procedure

Table 1. Failure Case from FMEA

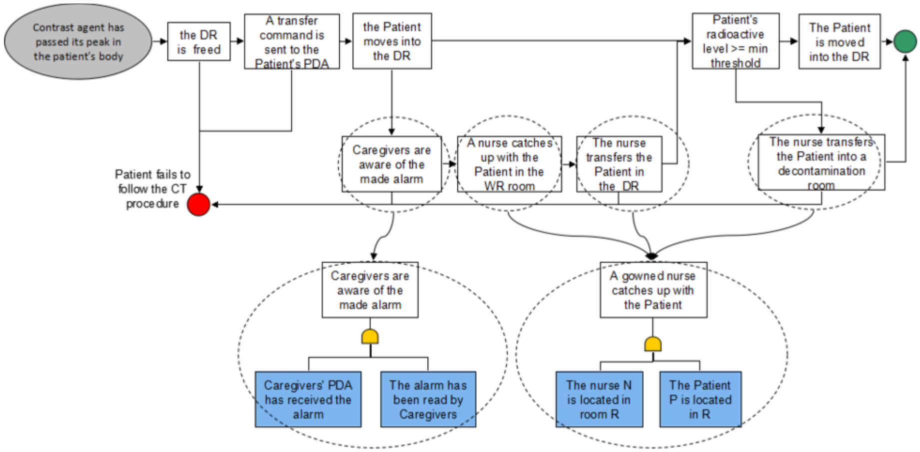

Figure 2. Dynamic Probabilistic Risk Assessment methodology Example

4. Preliminary Experiment and Results

To validate the feasibility of our PRM and DPRA methodology, in the following we present a preliminary experiment conducted on the case study described in Section 2.1.

For the sake of brevity, we will focus our attention on the last two stages of our methodology with respect to the instantiation of the PRM and its evaluation by means of the probabilistic model checker PRISM[12]. We refer readers to our previous work [8] to see a practical application of our approach in the generic context of Medical Devices.

With regard to the AmI-HS for a nuclear medicine (NM) department, we choose to analyse the failure case shown in table 1 and taken as a results of an FMEA. It is straightforward to infer that such situation can only happen subsequently to when the radioactive agent has been administered to the patient. What is not inferable is where the patient could be located when this hazard event occurs. In fact, the probability of the patient failing to following his/her examination procedure may change if, for instance, the patient is still in the WR rather than being in the DR and ready for examination. The AmI-HS of our case study deals with automatising and managing the examination procedure within the NM department. Therefore, we assume that by means of the dosimeter sensor, the system knows when to send a command to the patient's PDA that suggest to him/her to move onto the DR for examination. An FMEA is not sufficient to analyse the dynamics of such situation, hence this is where, by using the ET/FT formalism, a DPRA approach is of great benefit.

Fig. 2 shows a hazard scenario in which an ET/FT analysis helps in identifying the sequences of events that from the occurrence of the hazard state leads to success/unsuccess end states.

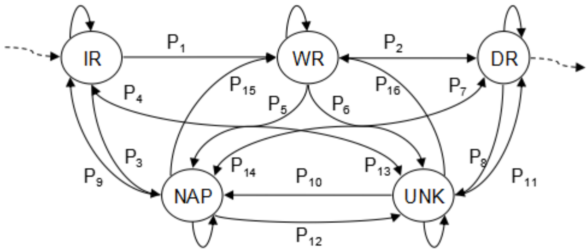

Figure 3. Context-MDP for patients

As it is clear, the ET scenario abstracts away from the spatial aspect related to where patients and caregivers are located. Such information differentiates various scenarios all having as a reference model that pictured in Fig. 2. A hazard scenario is then a means which drives the construction of the associated PRM.

In [8] we have already proposed how a hazard scenario can be mapped into a pure Markov Decision Process (MDP) risk model and, also, we have discussed the advantages in using an MDP model such as the introduction of the temporal aspect, and the capability of representing more complex scenarios due to the presence of loops and arbitrary reward functions on states and transitions. In this work we have defined a PRM based on an MDP extension we call Context MDP, or Cxt-MDP for short. Fig. 3 shows the Cxt-MDP which captures the behavioural movements of patients in the NM department case study. The states IR, WR, and DR represent the three rooms within the MN department. The two states "NA" and "UNK" model the fictitious spaces "Not Allowable" and "Unknown", respectively. The former allows us to take into account the cases in which an AmI-HS user either is within a not permitted area or is not in the area expected by the specific medical procedures encoded into the system. The latter considers all cases in which the AmI-HS is not able to determine the user's position within the department. This Ctx-MDP can be easily instantiated and adapted to model the stochastic process of moving from one place to another for each category of occupants. Moreover, our PRM allows us to also model the occupant's behaviour according to each context taken into account. In doing so we are able to minimise the model complexity with respect to the case in which a unique MDP is used. In our case study, for instance, the operator that receives patients in the AR is qualified to register them and to provide them with their RFID bracelet, whereas a nurse located in the IR is in charge of administrating the radiopharmaceutical to patients. Therefore, we can "personalise" the model by representing what is really needed for the purpose of risk assessment.

To model the hazard scenario of Fig. 2, we consider only two categories of occupants, i.e. caregivers and patients, and the three contexts of the IR, WR, and DR. To build a PRM we can abstract away details not needed to compute the risk. Thus, we choose to model the caregivers' states by considering not the real actions they can perform but rather the effects such actions have on the caregivers in terms of their availability to be engaged in corrective actions for mitigating risks. As a consequence, we model the caregivers' MDP with three states: Available (AV), Interruptable (INT), Uninterruptable (UNINT). To simplify the whole PRM, we instantiate this MDP for every context. We only adapt the transition probabilities according to the usual behaviour caregivers exhibit with respect to the activities they carry out in that context. As for the patients' model,

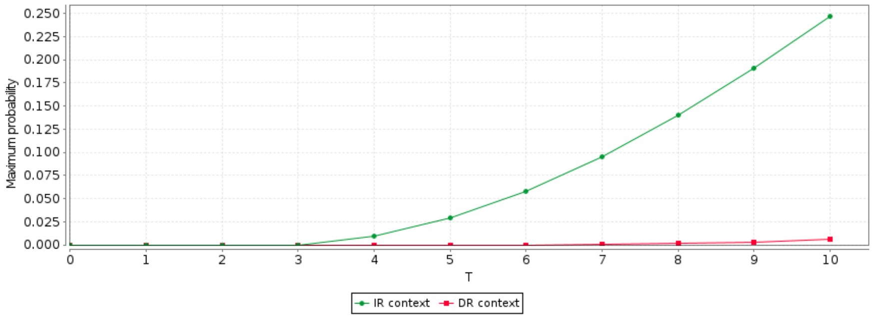

Figure 4. Probability of reaching a hazard state in either the IR or DR context

we differentiate it with respect to the context IR, WR, and DR. In all we consider to model the radioactivity level according to whether it is increasing (INC), in the appropriate range for examination (READY), out of range but not below a safe threshold (OFR), or of a safe level and decreasing(SLAD). In addition, in the IR context we also encode the states denoting whether the injection has been executed (INJ) or not (NOTINJ), by which in turn it is determined if the patient can leave the IR to move on into the WR.

We have realised our PRM by mapping it into a parallel composition of reactive modules[15] described and processed by the PRISM model checker. We want to warn the readers that the evaluations are obtained with respect to a stochastic model whose transition probability distribution does not represent actual measures taken by real situations of a nuclear medicine department.

Fig. 4 shows the probability, we denote P_c, that a hazard end state (which represents the occurrence of its negative consequences) is reached, given that the failure shown in table 1 happens. The Probability Computation Tree Logic [11] is the formal language used to express properties related to MDPs. In our case to compute P_c we define in the PRISM language the following expression `Pmax=?[F<=T "viol_state" AND "viol_ctx"]` which intuitively means "what is the maximum probability of reaching the state `viol_state` (negative consequence) of the context `viol_ctx` within T time units?" The graphs of Fig. 4 plots the value of P_c by considering for `viol_ctx` with respect to both the IR (green line) and DR (red line) contexts, respectively. In the model we take into account the delay between the time wherein a decision regards a human-based command is taken by the system and when it is actually performed by humans, i.e. in this case the patient moves on towards the DR. In fact, the picture shows a zero probability in the first time units in both graphs. Then P_c increases more in case when the patient stays in IR than when in DR because in this latter case the patient is already in the room where the examination can be promptly performed without waiting any longer.

5. Related Work

As far as in our knowledge only Grunke et. al in [16] define a Risk Analysis approach which combines a probabilistic model checking (PMC) technique with a traditional Failure Mode and Effects Analysis (FMEA). Particularly, in the broadest context of system safety the authors define a probabilistic FMEA, they call pFMEA, by using a Continuous-Time Markov Chain (CTMC) as a model for formally specifying the system and its interactions with the environment. As such, their focus is on analysing a stochastic failure model of system components, and the FMEA is used as a risk analysis technique to mainly identify and relate system components and failures.

In contrast, the methodology we presented is based on a Dynamic Probabilistic Risk Assessment approach which focuses on formally specifying risk scenarios and performing quantitative evaluation of risks in the specific context of Ambient Intelligence Heathcare Systems (AmI-HS). In detail, we defined a formal probabilistic risk model (PRM), based on a Markov Decision Process (MDP), to capture two important aspects of such systems, i.e. the context-awareness and the human factor. We also exploit a Probabilistic Model Checking (PMC) technique as a means to both specify the PRM and conduct risk assessment. We emphasise that our attention is on risk scenarios centred on the safety of patients and medical staff, thus considering not only the system itself, but also human actions, event concurrency, and non-deterministic situations.

Other works [1,17,18] in the context of AmI systems are more focused on verification and validation techniques and, as such, the approach is system-centred and not human-centred. Verification techniques presented by Augusto, and McCullagh [1] are based on modelling the behaviour of each device composing the AmI system as an automaton. In particular the authors discuss the use of timed automata and then the verification of behavioural properties written in Timed Computation Tree Logic to be checked by using a model checker. They also use temporal properties and finite state automata to, respectively, specify the properties and model the devices of an Intelligent Domotic Environment (IDE) system in order to verify its functional correctness.

Muñoz et al. [17] address the problem of AmI system security and dependability by focusing on a formal description and automatic verification of all possible interactions which may arise among system components. Specifically, the authors' research aims at studying and analysing the use of the AVISPA (Automated Validation of Internet Security Protocols and Applications) model checker to model and validate protocols in AmI environments. Neither the human factor nor the context-awareness are taken into account.

In [18] a design-time methodology is proposed to formally verify IDEs. The approach is based on using UML 2.0 State Charts as a formalism to model the behaviour of devices, the network, and the algorithms which control the system; the model is then verified against some logical properties expressed in UML computation tree logic (UCTL) by exploiting the UML Model Checker (UMC).

6. Conclusion and Future Work

In this paper, we have described a Dynamic Probabilistic Risk Assessment (DPRA) methodology which better addresses the problem of identifying and evaluating hazard scenarios for those Ambient Intelligence Healthcare Systems (AmI-HS), which are considered as Medical Devices (MDs), i.e. systems subject to an extensive regulatory process. Our approach takes advantage of traditional risk analysis and assessment techniques such as Failure Mode and Effects Analysis (FMEA) and and Event Tree/Fault Tree Analysis (ETA/FTA). The former useful for identifying hazards, whereas the latter to capture the dynamics of hazard scenarios, i.e. the sequence of events and actions which give a representation of how the system can manage problematic situations as a consequence of an occurred failure. Hazard scenarios are then encoded into a formal probabilistic risk model (PRM) we defined in this work and on which we concentrated our attention. Particularly, the PRM extends a Markov Decision Process (MDP) in order to capture two distinctive characteristics AmI-HSs exhibit: context-awareness and personalisation.

We applied the proposed methodology to a case study of an AmI-HS for a Nuclear Medicine department. In using a PRM we shown how risk can change with respect to both in which physical place the hazard happens and which are the actual conditions of all the occupants to be taken into account in the hazard scenario. A model for this case study has been defined and the risk assessed by exploiting the probabilistic model checker PRISM as a powerful tool both to implement the PRM and to assess the risk. As a result, our methodology seems to be promising in supporting risk analysis and management for AmI-HSs.

There are some aspects which we would like to consider as future work. As for the methodology, investigating the interaction among multiple scenarios is a first research activity we would like to conduct for consolidating the safety evaluation of AmI-HSs. For this purpose, an interesting point we are going to investigate is the automatic generation of variants of risk scenarios by appropriately combining those identified as fundamental ones. A further issue concerns the severity factor which usually is considered dependent only on the final consequences of hazards, without taking into account other variables of interest. As a first step, we would consider the two dimensions treated in this work, i.e. the spatial and the human ones. With regards to our PRM, it could be of great benefit to implement a tool by which a PRM can be formalised and analysed directly so as to allow us to conduct a stronger and deeper campaign of experiments.

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Change Impact Analysis for Context-Aware Applications in Intelligent Environments

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Abstract. As software systems for context-aware applications and intelligent environments become increasingly complex and adaptive, the need to understand and predict the impact of changes grows. Such changes may manifest themselves (1) as alterations in the way users behave, (2) as software customizations to handle new requirements, and (3) as variations on the dynamic context in which intelligent environment systems are deployed and operate. Such internal and external changes may be anticipated or unforeseen in nature. With reliability being a key concern for intelligent environments, we revisit in this work the state-of-practice on *change impact analysis* (CIA) – a well-known methodology in software engineering – and investigate to what extent it can be applied and enhanced to contribute to the development of more reliable context-aware adaptive applications to increase the confidence in intelligent environment systems.

Keywords. Change impact analysis, context, rapid decisions, reliability

1. Introduction

Over the past decade, intelligent environments have grown in complexity as distributed software and hardware platforms almost autonomously and collectively operate to transparently and non-intrusively support users and address their needs during their activities of daily living. It is inevitable that some software components undergo changes as they are customized to correct errors or to address new requirements. Such modifications may trigger subsequent changes in other components and the potential consequences of these side-effects may not always be clear upfront or desired. That is why the objective of *change impact analysis* [1] in software development is to provide an accurate understanding of the implications of changes, such that stakeholders can plan and make better informed decisions.

Change impact analysis is a well-established methodology in the software evolution domain to manage change, usually at the level of code modifications. However, for intelligent environments and context-aware applications, the notion

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of *change* imposes more far-reaching challenges. Contrary to applications that are context agnostic, the situational awareness of intelligent software systems causes them to change not only after modifications in the program code (i.e. *internal* changes), but also when the context of the user or the operational circumstances of the intelligent system (i.e. *external* changes) evolves. The key problem that we aim to highlight in this work is the fact that state-of-practice impact analysis methodologies are not sufficiently equipped to reason upon the impact of (un)planned changes, especially for dynamically adapting software systems such as those that are frequently found in intelligent environments.

Recent work [2,3] has explored model checking as an approach to verify consistency, safety and reliability properties of context-aware applications and intelligent environments. Consistency checking for a context-aware system in a steady state is already a non-trivial endeavor. We now step it up a notch in the sense that we aim for reliable *evolving* intelligent environments and context-aware applications that are *in transition*. This means we must ascertain that enacting change in complex intelligent distributed software systems causes these systems to evolve from one consistent reliable state to the next with as little undesired side effects as possible. It is clear that analyzing the impact of changes now becomes even more arduous. These changes can be both internal and external in nature as they are triggered by different stakeholders (i.e. from software developers at design time to end-users at runtime). For context agnostic systems, the software developer has a good understanding of the intended operational circumstances, and changes can be *planned* at design time or during deployment. For applications with behavior largely driven by external influences such as intelligent environment applications, changes can no longer be planned but must be *anticipated*. This is why we claim impact analysis evolves from a pure static design time concern towards a dynamic runtime concern. Indeed, changes may manifest themselves (1) as alterations in the way users behave or interact with the system, (2) as software customizations to handle new requirements, and (3) as variations in the dynamic context in which intelligent environment systems are deployed and operate. In this work, we revisit the state-of-practice on change impact analysis in the software engineering domain and investigate to what extent it can be applied and enhanced to contribute to the development of more reliable context-aware adaptive applications and intelligent environment systems.

In section 2 we provide an overview of related work in the domain of impact analysis and change management. To illustrate the complexity of change impact analysis for context-aware applications in intelligent environments, we provide a motivating example in section 3. Section 4 provides a taxonomy of changes that a more encompassing impact analysis methodology fore reliable intelligent environments should support. In section 5, we elaborate on our initial endeavors in this area. We reflect back on our work in section 6 before concluding with our final thoughts and suggestions for future work in section 7.

2. Related work

In this section, we briefly discuss relevant related work on change impact analysis in the software evolution domain. While already almost two decades old, Arnold's book [1] on software change impact analysis highlights many of the important topics, including the need for *traceability* between requirements and design elements of the software architecture, and the representation of *dependencies* that determine the consequences of changes. More recently, Lenhert [4] presented a taxonomy of impact analysis methods. Based on a broad literature review, he presents a multitude of criteria – ranging from the scope of analysis, the granularity of changes and impact, up to the availability of tool support – to classify and compare various impact analysis approaches.

A sound representation of dependencies is instrumental to analyze and measure the impact of changes. German et al. [5] proposed the concept of change impact graphs to determine the impact prior to the actual enactment of code changes. Their method recursively defines the dependency graph $G(f)$ of a function f based on the other functions that can be reached by f. Other works, such as those by Lock et al. [6] and by Tang et al. [7], focus on how to use probabilistic causal relationships to asses how changing requirements and design decisions may affect design elements of a software architecture. These kinds of works go beyond rule based inference in the analysis phase and, for example, leverage Bayesian Belief Networks (BBN) to quantify the likelihood of change impact.

Briand et al. [8] proposed an UML-based method for impact analysis. Their model-based methodology is used to predict the cost and the complexity of changes in order to decide whether to actually implement these changes in a next iteration of a software release. It first starts with a consistency validation phase of the UML models of the system. The impact analysis itself is then carried out between two different versions of the UML model. Their framework offers a set of change detection rules with respect to a given change taxonomy. Model elements that directly or indirectly undergo changes are formally represented by impact analysis rules defined in the Object Constraint Language (OCL).

When software companies have to deal with customers with individual requirements and expectations for specific features – also not that uncommon when deploying context-aware systems adapted to the needs of individuals in an intelligent environment – they usually address such concerns by adopting a Software Product Line (SPL) [9] development methodology to manage common and variable features within a software product line. Both Díaz [10] and Angerer [11] proposed an impact analysis method for derived variants within a software product line or product line architecture. The objective is to measure the impact of customized variants when merging modified features back into the original SPL. The key contribution of these works is that they offer variability-aware program analysis without having to analyze each and every variant of the software product line independently. The combinatorial explosion of feature combinations in the product line (i.e. customization towards the clients or end-users) would make this an intractable impact analysis task.

An in-depth survey is beyond the scope of this work, but it is clear that most of the research on this topic is on program code and design model analysis methods in the software evolution domain. The change impact analysis phase is still carried out at design time, i.e. prior to the actual code modifications. The same is true even if the software engineering methodology pursues an iterative development life cycle to support customization per client. In this work, we borrow

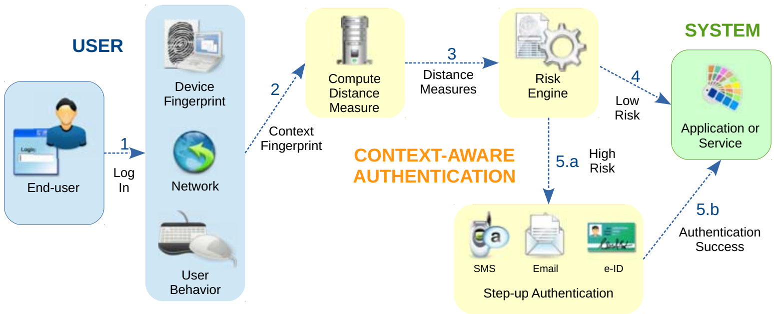

Figure 1. A motivating example on user-friendly context-aware authentication: the context of an individual is used for identification and to quantify risk. If needed, the intelligent authentication system will trigger stronger methods of authentication when the situation demands it.

concepts from the state-of-the-art on dependency graphs, application models, and variability. We investigate to what extend these works can be enhanced for change impact analysis where change is not only a design time concern.

3. A motivating example on user-friendly context-aware authentication

In this section, we will briefly introduce a motivating example to illustrate the impact of change in a non-trivial context-aware application. The application builds upon previous work [12] on the use of context information to offer an intelligent platform for authentication that enables a more user friendly alternative to the intrusive and cumbersome login/password style of authentication.

3.1. Context-aware step-up authentication

Without going into the technical details of our previous work, we provide below a step-wise description of how the user-friendly context-aware authentication works. See Figure 1 for a conceptual overview of the system. The context-aware authentication compares context fingerprints. These fingerprints are in essence an aggregation of various context attributes that collectively can distinguish users or entities from one another.

1. The authentication platform uses and combines different types of context to distinguish and identify a user (time, location, device, behavior, etc.)
2. The different context parameters are aggregated from various context sources to establish a global context fingerprint of the user.
3. The context-aware authentication system compares the current context fingerprint against previous fingerprints of a known individual.
4. Depending on the matching score of the context fingerprint, the authentication system may be confident enough that it has identified the user (without having to ask for credentials in a fairly intrusive way).
5. Otherwise, if the matching score is deemed too low (or alternatively the risk score for mis-identification too high), the system may ask the users to identify themselves with a strong form of authentication.

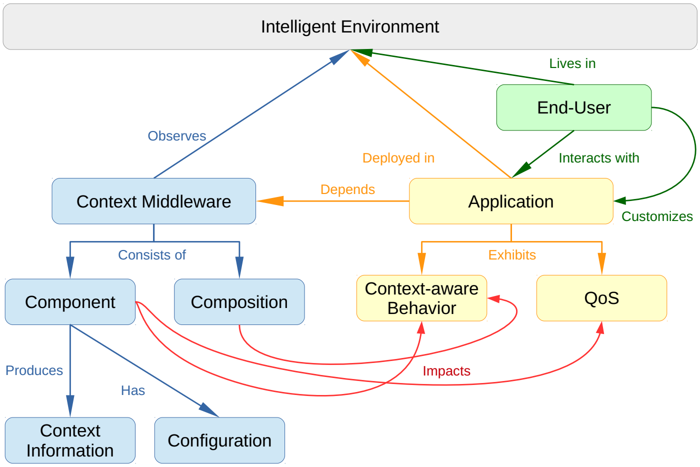

Figure 2. Impact analysis on context-aware applications in intelligent environments.

The overall objective of using context for authentication is to get rid of weak or hard to remember complex passwords. DARPA's Active Authentication program [13] is pursuing similar ways for a continuous authentication based on context and user traits that can be observed through how people interact with the world (e.g. keystroke patterns, mouse and eye movements, cognitive aspects). These techniques have been demonstrated successfully, but long-term stability of behavior patterns is a concern. Our work specifically focuses on the impact of changes when modifying the context sources that characterize human behavior.

3.2. Generalization to context-aware applications in intelligent environments

The above user-friendly authentication system is merely an example of an advanced context-aware application. While it might not be the prototypical example for intelligent environments, it shares a lot of similarities with applications that are more characteristic for these areas, such as ambient assisted and independent living scenarios. We will therefore now generalize the main characteristics of the application, as depicted in Figure 2, to illustrate that it covers a broad range of context-aware applications:

- Context information is exploited to create an understanding of the user, such as his or her identity, current location and situation, activities, etc.
- The context-aware behavior of an intelligent software system is often adapted and customized to the preferences and needs of the individual.
- The quality of the context (e.g. accuracy) and the quality of service of the context-aware behavior (e.g. real-time reaction) play an important role.
- The acquisition and management of context is often decoupled from the business logic (applications and services) that depends on it.

It is clear that in such an ecosystem various changes can have an unforeseen impact on the overall reliability of a context-aware application in an intelligent environment. Often the internal and external dependencies have not been made explicit, which makes it challenging to analyze the impact of change and hence the reliability of the system at design time.

4. A taxonomy of changes in intelligent environments

In this section, we will highlight how a variety of changes can affect the reliable operation of an application or service within an intelligent environment. We will not revisit analyzing the impact of typical changes that have already been identified by the state-of-the-art, but mainly focus on those topics that deserve much more attention in contemporary change impact analysis techniques and methodologies.

In the subsections below, we consider the core functionality of the authentication platform in the motivating example of section 3.1 as fixed. Its objective is to identify and authenticate an individual in a non-intrusive way by any context means available.

4.1. Functional changes to contextual dependencies

A functional change in the context middleware includes the addition, removal, replacement or reconfiguration of any context sources. With context sources, we refer to application dependencies to both the type of context information as well as the software or hardware component that provides that context information.

A reason to modify the context middleware of our authentication platform is that some sources no longer provide sufficient entropy, i.e. they provide too little useful information to distinguish individuals from one another based on the context fingerprints alone. For example, a device fingerprint obtained through a web browser may aggregate context attributes such as the screen height and width and the user agent string. However, for mobile devices some context-based device fingerprints may not contain sufficient entropy to distinguish different devices, as illustrated in our previous work [14]. Such problems can be mitigated by adding additional context attributes in the device fingerprint, such as an HTML5 canvas fingerprint taken by a browser to better characterize the device.

Changes in the context middleware can affect the similarity assessment with previous context fingerprints in the application. Some context fingerprints may still make use of old (and now removed) context sources or attributes, causing unexpected mismatches. If this change is not taken into consideration in the computation of the similarity score and the overall risk assessment, previous context fingerprints may be discarded without valid reasons.

> *The change impact analysis method should account for changes in the dependencies on context sources and attributes the application relies on.*

4.2. Non-functional changes to contextual dependencies

Non-functional changes can also occur when components are reconfigured, added to or removed from the distributed software architecture. For example, the sampling rate of a context source or the amount of information it provides may evolve after a change, leading to a possible performance impact on the application, especially when the latter has to process more or more frequent context updates.

For example, our context-aware authentication platform leverages location information and exploits the fact that an individual cannot be at two different places at the same time. Faster location updates improves the quality of the risk assessment of our authentication platform but at the expense of a higher performance or latency impact in the authentication platform.

Changes in the composition or configuration of the context middleware can affect the context-aware behavior and quality of service of the application.

4.3. Changes by the end-user stakeholder at runtime

Some state-of-practice change impact analysis methodologies support traceability between (non-)functional requirements and design elements in the software architecture. These techniques are targeted towards the developer as the stakeholder of the system that initiated the change at design time. However, context-aware applications often also adapt (and hence *change*) upon request of their users to address their evolving needs and preferences. End-users are also important stakeholders in the system, but the impact of end-user initiated changes is usually not accounted for in the impact analysis methods.

For our authentication platform, a simple change such as changing ownership of a mobile device could have an influence on the way a user is implicitly identified by the system, because the device fingerprint will remain the same but the way one interacts with the device will most likely change.

User initiated changes that are allowed by the system at runtime should be represented as explicit dependencies to be able to analyze their impact.

4.4. Unanticipated contextual changes

When creating complex applications, software architects and developers make a lot of decisions that are related to functional or quality (non-functional) requirements. Some of these decisions are based on expertise, budget constraints, personal experience or other assumptions that are not made explicit in the documentation. For example, the application developers may not account for the fact that context sources may become unavailable or produce erroneous or inconsistent values, hereby jeopardizing the functionality of their applications.

In our authentication application example, the use of location information in the fingerprint is not mandatory. However, if a previous context fingerprint has location information (WiFi or GPS-based), then the application assumes all follow-up context fingerprints will contain the attributes as well to analyze the similarity.

Assumptions about the presence of context sources, as well as the quality of the information they produce, should be explicit context dependencies.

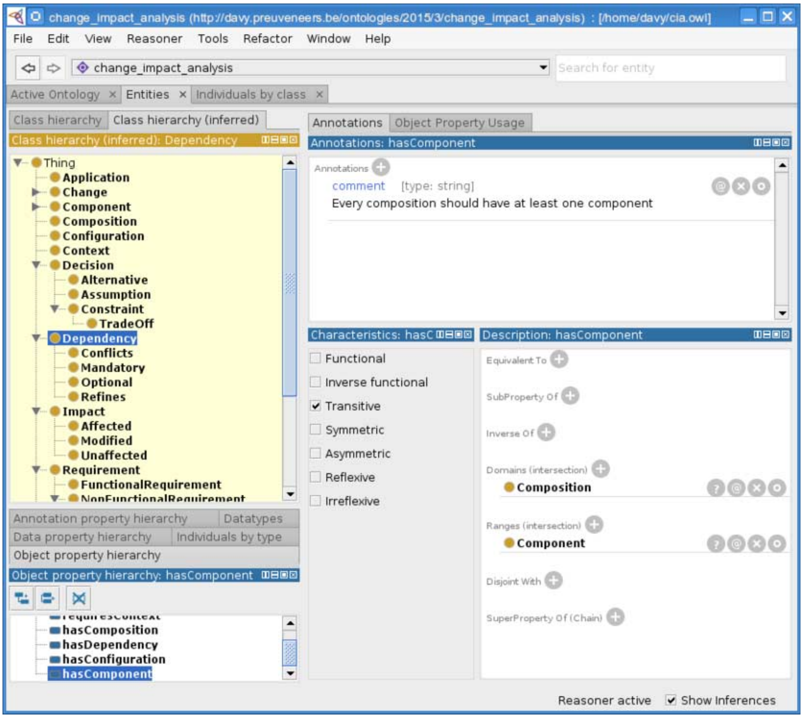

Figure 3. Using ontologies to formally model dependencies in context-aware applications.

5. Towards change impact analysis for context-aware applications

In this section, we will discuss our first steps towards an adapted methodology for change impact analysis for context-aware applications in an intelligent environment. We will highlight where we build on previous work and best practices from the literature.

5.1. Ontology-based modeling and annotation of dependencies as a graph

In our approach, we also model the knowledge we have about the intelligent system, including its design (components and connectors), constraints, assumptions, conflicts, as well as decisions, alternatives and the rationale driving the design and the dependencies among design time and runtime decisions.

Rather than modeling a system in UML notation, we adopted an ontology-based approach that offers us more formal semantics and reasoning capabilities out of the box. Ontologies (in OWL format and edited with the Protégé tool[2] as depicted in Figure 3) allow modeling of dependencies as transitive properties to analyze direct and indirect impacts. It allows us to reason about whether a change means a component is modified (direct change), remains unaffected, or is affected (indirect change) because one of its dependencies has changed. The

[2]http://protege.stanford.edu/

disadvantage is that ontologies do not offer the means to quantitatively measure the impact of changes.

5.2. Traceability of requirements and contextual variability of the system

Conceptually we model classes and properties in an ontology. As a result, the ontology represents a meta-model for change impact analysis. If we want to apply this meta-model to, for example, our context-aware authentication platform, we have to instantiate the relevant classes and properties. This includes instances (or individuals) for at least the following classes and properties:

1. Components within the application
2. Requirements, and components that fulfill them
3. Optional and mandatory context dependencies
4. Design assumptions and constraints

Once we have modeled the application with sufficient detail, we can analyze the impact of changes.

5.3. Representing change and impact within the ontology

Representing change in a context-aware application would boil down to having two ontology instantiations, and have tool support to automatically detect and discover the differences between both model instantiations. Protégé offers tool support to view the differences between two ontologies. However, to simplify analyzing and reasoning upon change and have better traceability between the changes and the entities that are impacted, we opted to directly model changes as a delta in the original ontology model instance.

5.4. Verify consistency before and after change

Ontology inference engines (such as the HermiT 1.3.8.3 reasoner in Protégé 5) are based on complex description logics, rather than the less complex rule engines. The advantage of using description logic reasoners is that analyzing subsumption is very straightforward. This allows to infer whether some entities in the ontology become semantically equivalent with the *owl:Nothing* OWL class identifier. The predefined class extension of *owl:Thing* is the set of all class instances, whereas *owl:Nothing* is always the empty set. If an entity is equivalent with *nothing*, it basically means that it does not exist. For optional components, it means the component is gone. For mandatory ones, we can conclude there must be a consistency issue. Furthermore, advanced tools can explain why ontologies may be inconsistent. We exploit this capability to detect whether *change* instances in our ontology trigger inconsistencies in the ontology instance of our application.

5.5. Analyze design decisions and propagation of changes

The additional advantage of semantically modeling an application with ontologies, compared to UML, is that implicit or indirect relationships between the design elements in the architecture, can be automatically inferred. Reflexive, transitive

Property	Value
# classes	176
# object properties	39
# individuals	42
DL expressivity	AL+

Table 1. Change impact ontology metrics

Change	Time (avg.)
Add context fingerprint	531 msec
Replace location component	876 msec
Change device ownership	796 msec
Impact faulty component	628 msec

Table 2. Change impact analysis performance

or symmetric properties are powerful characteristics in the semantic definition of a dependency relationship when analyzing the propagation of changes.

When a design *assumption* or *trade-off* formally states that an artifact (e.g. a component or context attribute) should not change, but the meta-properties of the relationships infer an impact, unexpected side effects can be detected. Whether this is a big concern, is something that should be investigated by the software architect or developer. When a violation is detected against a design *constraint*, then the proposed change would affect the consistency of our application.

6. Discussion and experience with motivating example

Our approach is still rough around the edges, and thus far, has been validated on one use case being the context-aware authentication application in section 3.1. In the previous sections, we highlighted benefits of our technique. In this section, we mainly focus on the shortcomings we hope to address in future work.

6.1. Quantitative assessment of change impact

A first concern is the fact that semantic ontology reasoners are very good at analyzing the impact of changes, but these tools cannot *measure* the impact or even the likelihood of an impact. Our approach gives a fairly black and white picture. It does not allow us to prioritize changes with respect to their impact.

When our tool infers there is a possibility of an impact, whereas our personal experience or expertise as a developer tells us otherwise, we must model these design assumptions into the application ontology instance.

6.2. Automating test case generation with change boundaries

Many model checker tools are able to automatically produce counter examples to illustrate what kind of steps are needed to let the system evolve to a state that is inconsistent with some predefined safety or reliability properties.

Unfortunately, this is not possible for our change impact analysis approach. In theory, the number of changes that can be applied on a system are endless, and as such there will always be changes that will jeopardize the consistency and reliability of our application.

What is needed is either a catalogue of common changes, or way to set the boundaries for the kind of changes that can be expected or that developers believe should not harm the reliability of the system. The automatic generation of these kind of test case is currently not supported.

6.3. Performance of the analysis

Table 1 lists various characteristics of our change impact ontology for the authentication platform. It provides some statistics on the number the classes, instances and relationships among them, as well as a characterization of the complexity of the change impact ontology. Table 2 lists 4 simple experiments and the average execution time of 5 runs to analyze the impact of each change:

- **Add context fingerprint**: Add the HTML5 canvas device fingerprint
- **Replace location component**: Replace the GPS with the WiFi component
- **Change device ownership**: Measure similarity of stakeholders
- **Impact faulty component**: Infer all dependent components

This example is still fairly small and simple with very reasonable performance results. However, preliminary experiments with artificial ontologies with more than 1000 axioms showed that the analysis of a single change − adding a context feature in the authentication framework − can be carried out in less than a second on a Dell Optiplex 7010 desktop machine, with 16GB of memory and an Intel Core i7-3770 quad-core CPU running at 3.40 GHz. We have not carried out extensive experiments, but plan to enhance the analysis tool with a SPARQL query front-end such that benchmarking can be automated and produce more reliable performance results.

6.4. Integration with other model checking tools

Our change impact analysis technique focuses on a key specific aspect that may harm the reliability of a context-aware application or an intelligent environment. There are various concerns that our technique does not detect, and for which other tools are much more adequate.

Ideally, we should find a way to interlink all these reliability analysis tools in a common test suite such that developers can analyze all of them with a simple click on a button, or schedule them as part of a continuous integration and automated test execution environment such as Jenkins.

7. Conclusion

In this work, we discussed the state-of-practice on change impact analysis in the software evolution domain, and we investigated to what extent it can be applied and enhanced to contribute to the development of more reliable context-aware adaptive applications. The contribution of our work was mainly focused on external dependencies that influence the context-aware behavior and quality of service of an application. Additionally, we semantically modeled a variety of dependencies, such that ontology reasoners can make implicit relationships explicit so that the impact propagation can account for these hidden dependencies.

As future work, we will further explore how we can add more quantitative data to our analysis framework such that we can measure the likelihood and size of the impact. Additionally, a formal representation of bounded changes would allow us to automate the generation of test cases to automatically analyze which permitted changes would jeopardize the reliability of our applications.

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An Introduction to Continuous Interaction

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Abstract. Users are currently expected to benefit from the concurrent use of different computing devices and applications: Personal computers for an easier content production, mobile devices for increased mobility and context-awareness, wearable devices for more transparent health-related data acquisitions, etc. However, the simultaneous use of different devices and applications could be perceived as disruptive or unproductive, due to the need of additional settings, lack of integration, etc. As a first step to overcome this problem, in this paper we introduce the notion of Continuous Interaction (CoIn) systems. These systems intend to promote the simultaneous use of multiple devices and applications to complete tasks in a more effective, flexible and easy way. To achieve that goal, a set of human-centred design principles have been figured out to enable users to seamlessly share tasks across multiple devices, independently of the software applications supporting their completion. The case study of a Mobile Forensic Workspace (MFW) will be presented to highlight the benefits that CoIn systems could bring to the Ambient Intelligence (AmI) and Ubiquitous Computing research fields.

Keywords. Human-Centred Design, Workflow Modelling, Ambient Intelligence, Ubiquitous Systems, Usability

1. Introduction

Nowadays, it is increasingly common to make use of several computing devices to carry out our daily tasks in different situations or environments: while moving, at home, at the office, etc. In this manner, smartphones, tablets, personal computers and other devices coexist to offer a rich computing environment in which we spend much of our leisure and professional time.

Ideally, end users are expected take advantage of the characteristics of each specific device and application: Personal computers for an easier content production, mobile de-

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vices for increased mobility and context-awareness, wearable devices for more transparent health-related data acquisitions, etc. Nonetheless, these devices, and their underlying platforms (operating systems, middleware, frameworks, etc.), have not been designed to work together in an integrated manner. In consequence, for instance, most of us have to rely on external Cloud-based tools (like Dropbox, Box, iCloud, OneDrive, etc.) or remote services to synchronize our information between our own devices. As an example, Figure 1 depicts, as a UML state diagram, an increasingly usual workflow when composing an e-mail, which can be considered as an straightforward and common task.

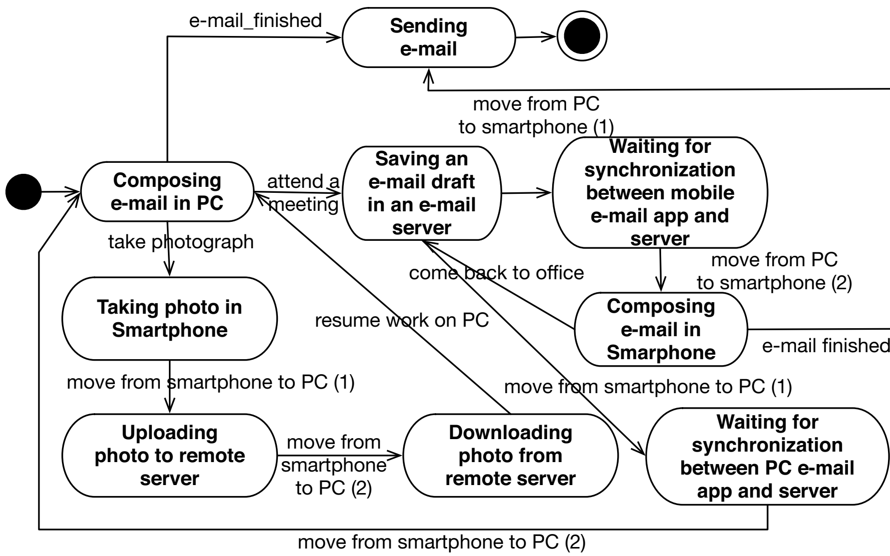

Figure 1. Increasingly common workflow when composing an e-mail, depicted as a UML state diagram.

These types of workflows, even in simple cases (like the one depicted in Figure 1), can be very disruptive, slow (i.e., we have to wait for the upload and download of information from remote services), resource consuming and even difficult to carry out for many users. A possible solution could be to shift the focus from sharing information between devices and applications, to actually share the tasks to be completed between multiple devices and applications. In consequence, the software should be designed to allow the user to interact in a continuous way with multiple devices at the same time, taking advantage of their distinctive capabilities to more easily complete a certain task through several applications and underlying platforms.

As a first effort to achieve that goal, in this paper, we present the notion of Continuous Interaction (CoIn) systems through the description of their human-centred design principles. The idea is to highlight their objectives and key end-user features. Moreover, the design principles could be taken as a basis to have a clearer notion on which features should be incorporated into a software system to allow multiple devices to be concurrently used to more easily carry out certain tasks. In fact, the design principles could aid into producing designs for a wide range of computing systems, such as ubiquitous, AmI, etc.

The case study of a Mobile Forensic Workspace (MFW) [1][2] is used to illustrate the problem, and the benefits that CoIn systems could bring to software usability and productivity.

The remaining of this paper is structured as follows. In Section 2, the case study of the MFW is presented. Section 3 describes the human-centred design principles that a CoIn system should meet. In Section 4, the MFW case study is revisited, with the intention of highlighting the benefits that the adoption of those principles could bring to this kind of collaborative, AmI systems. Some related work is summarized in Section 5, including a description of some recent technologies that could allow to implement CoIn systems. Finally, the conclusions and some lines of future work are presented in Section 6.

2. Case Study: A Mobile Forensic Workspace (MFW)

This section presents the case study of a Mobile Forensic Workspace (MFW). The idea is to make explicit how the use of multiple devices can decrease usability (even when using different instances of a single application), if a software system has not been designed to achieve that goal. As it will be described, the usability decrease may also impact in other quality properties like security or reliability.

Firstly, a summary of the objectives and overall characteristics of the MFW are presented. After that, we highlight the usability difficulties that the users have found while using the MFW on multiple devices.

2.1. Introduction to MFW

A Mobile Forensic Workspace (MFW) has been proposed to facilitate collaboration, data collection and sharing in scenarios with multiple victims. In these scenarios, official agencies, like regional police forces or Interpol (Interpol DVI forms, available online at: `http://www.interpol.int/es/INTERPOL-expertise/Forensics/DVI-Pages/Forms`), apply protocols of action intended to support victim identification in natural disasters, accidents, terrorist attacks, mass murders, etc. These protocols try to deal with how victim data is collected and how professionals (e.g., members of police forces, forensic experts, etc.) have to cooperate to complete their tasks.

MFW is considered as an AmI system, since it poses the following features:

- **Sensitive:** It is able to automatically detect nearby professionals collecting data, and the location of each victim (and his/her associated personal effects) whose associated data was previously collected into the workspace.
- **Responsive:** The detection of nearby professionals is notified to the users, and makes it possible to communicate with them through the workspace in order to coordinate the data collection activities.
- **Adaptive:** It is adaptable to the needs of many official agencies, since it can be configured to support the collection of many different types of data (location, photographs, descriptive texts, dental characteristics, radiographs, body sketches, etc.), depending on the applied official protocol of action.
- **Transparent:** The collected information is automatically and transparently disseminated among nearby professionals, even if they are applying heterogenous protocols of action involving the the collection of different data.

- **Ubiquitous:** MFW has been designed to be used in mobile platforms. Additionally, the automatized location of victims and personal effects (after their registration into the workspace) is meant to be achieved through small location "tags" that are integrated into the physical location of the disaster.
- **Intelligent:** It detects data conflicts, tries to automatically solve them and, in case it is not possible, it tries to communicate the involved professionals to manually solve the conflict.

AmI systems may contribute to enhance disaster management [3], and emergency services in general [4]. In consequence, AmI systems may be appropriate for official agencies intending to use ICTs to improve the coordination and cooperation between the professionals that have to collect data in forensic scenarios with multiple victims.

2.2. Observed Usability Problems when Using Multiple Devices at the Same Time

In scenarios with multiple victims, many of the in-situ tasks involve both collecting information and accomplishing physical works (e.g., body recoveries, security increases, aiding to alive victims, etc.).

In the current approach to the MFW, professionals are intended to use a unique personal device at the same time, which, in this case, can be a tablet, an smartphone or a personal computer. However, the professionals do different works depending on the needs, which, in many cases, should involve a device change (to increase mobility, allow an easier content production, etc.). By design (i.e., to increase security), in MFW, each device must have a digital certificate that authorizes a specific user to incorporate and share information. In consequence, to change from one device to another, the user has to install his/her personal digital certificate in the new device, re-enter some individual access credentials and make the appropriate interactions to continue with the information collection just at the same point in which it was interrupted. Additionally, the professional should uninstall the digital certificate and log-out from the previous device, in order to avoid security issues. An example of this device change workflow has been depicted in Figure 2 through a state diagram.

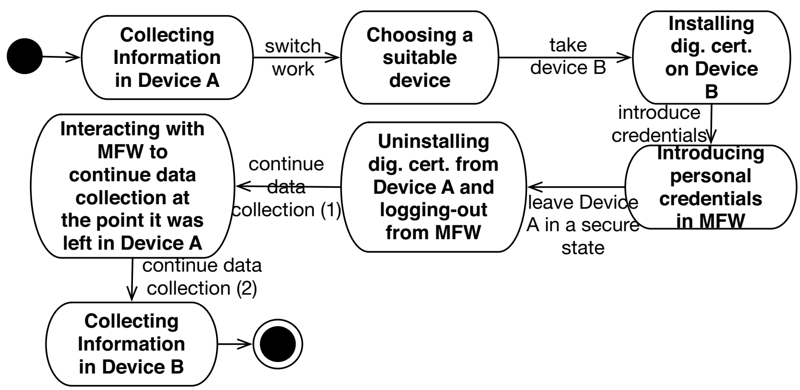

Figure 2. The current workflow for changing from one device to another in MFW, depicted as a UML state diagram.

Due to this potentially complex and disruptive workflow, users trend to avoid device changes. To do that, we have observed the following behaviors:

- Either they stop using the MFW while carrying out different works, and then they return back to use it to introduce the information that they have collected, commonly, by manual means,
- or they exchange their personal device with another professional for a while, thus making the authoring mechanisms completely useless.

Consequently, in MFW the use of multiple devices by a professional, not only decreases usability, but also negatively impacts on the security of the workspace and the reliability of the collected information (i.e., the authoring may not be clear, a user may change the information collected by another user, etc.).

3. Continous Interaction (CoIn)

In this section we introduce the notion of a Continuous Interaction (CoIn) system, which is a software system designed according to, at least, the following four design principles, which will be detailed in the following subsections:

1. The task is the element to share, not the data.
2. Seamless completion of tasks by several users using multiple devices and different applications.
3. The applications should explicitly recommend device and application changes to the user.
4. Continuous interaction.

These principles intend to leverage the *tasks* to become the central point of any user interaction, in order to facilitate multi-device and multi-application interactions, while increasing usability. As a matter of clarification, the conceptualization (i.e., the metamodel) of a *task* is depicted in Figure 3 as a UML class diagram. That conceptualization has been extracted from the AMENITIES conceptual model for collaborative systems [5].

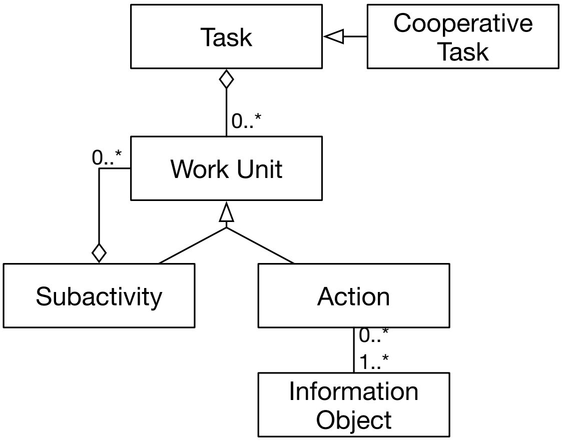

Figure 3. Metamodel of a *Task*, extracted from the AMENITIES conceptual model [5] and depicted as a UML class diagram.

3.1. The task is the element to share, not the data

Most current software systems allow an easy data sharing through different mechanisms: cloud-based storage services, shared databases, etc. These mechanisms enable the interoperability between different applications and devices.

However, sharing data is not enough to facilitate an user to seamlessly interact with multiple devices and applications to complete a specific task. In fact, the data that the user manages does not contain enough information to easily continue interactions between different devices and applications. To do that, the tasks themselves should be shared, including (but not limited to) the following information:

- The data that the user is managing.
- The application context, that is, the specific point in which an application is being executed by the user at a given moment (i.e., the user is composing an e-mail, taking a photograph, etc. within a specific application) to complete the task.
- The user context, that is, at least, the location of use, the collection of nearby people, hosts and accessible devices, as well as to changes to such things along time [6].
- The task context, that is, the workunits, actions and subactivities that the user is carrying out at a certain time.

In this way, CoIn systems could enable users to more seamlessly switch devices and applications to complete tasks.

3.2. Seamless completion of tasks by several users using multiple devices and different applications.

Nowadays, user cooperation is increasingly common in software systems to be able to complete complex tasks in a more productive manner.

Task sharing mechanisms should leverage cooperation by not only providing the data to be shared, but also contextual information about the other users, their application contexts and their tasks' context (i.e, the work units, sub-activities and actions that they are carrying out). In consequence, there could be more natural software mechanisms for end users to cooperate and use the joint benefits of heterogenous devices to complete their tasks.

Moreover, using multiple devices and applications should be as less disruptive, fast and easy as possible. In fact, users should not need to carry out configuration steps to switch between different devices and applications to complete a specific task.

In order to carry out that goal, software systems could make use of several mechanisms to allow a more seamless transition between devices and applications:

- Software systems could use context-awareness mechanisms to proactively detect when a user will switch from one device or application to others, and to transfer the tasks that are being carried out to them. In this manner, the software could anticipate to the user, who will find the other device or application completely ready to continue his/her tasks.
- Tasks could be represented using the *file* metaphor. Currently, users make a very active use of this metaphor to organize their daily tasks. In this way, representing tasks as files could be helpful for end users in order to better understand task sharing, task transition between devices and applications, etc.

3.3. The applications should explicitly recommend device and application changes to the user

The benefits of moving between devices and applications may not be directly obvious for many users. Indeed, the user may not know which are the benefits of using different devices and applications to carry out a task. Therefore, the applications should provide recommendations to move from one device or application to others, depending on the data to be managed and the user, application and task contexts.

To achieve that goal, applications and devices could explicitly announce their characteristics to others within their context. Intelligent systems could decide when it is more appropriate to complete a certain task in each specific device or application, and recommend it so to the end user. The recommendation should be presented together with an explanation about why the device change is allowed, and what are going to be the benefits for the end user. In this way, the user is provided with enough information to understand why it should be appropriate to continue his/her tasks in other devices (e.g., increased mobility, improved computing power, availability of sensors, etc.).

3.4. Continuous Interaction

Software systems should be designed to always allow the user to carry out an uninterrupted flow of interactions to complete a task. In consequence, their design should have a focus on improving reliability as much as possible, thus increasing the perceived fault tolerance, availability and recoverability [7].

Therefore, the design should take into account mechanisms focusing on avoiding the disruption of the user interaction upon network interruptions, unavailability of users or computing resources (battery, memory, etc.), etc.

4. Revisiting the MFW

The MFW is currently being re-designed to make more explicit the tasks that need to be carried out by professionals (according to the Interpol DVI Forms), while supporting an improved cooperation and facilitating multi-device interactions. To achieve that goal, the different CoIn design principles are currently being applied as follows:

1. *The task is the element to share, not the data:* Instead of focusing on collecting forensic data, the MFW will focus on the completion of forensic tasks. Those tasks will be the object that will be shared among professionals, rather than the data. Professionals will be able to share tasks, partially complete them, reassign them to others, etc. In this manner, we expect professionals to have a clearer mindset about what tasks they need to do, and the activities (involving data collection) that will need to be done in order to complete them.
2. *Seamless completion of tasks by several users using multiple devices and different applications:* In order to overcome the issues presented in Section 2, a task model has already been designed to transparently synchronize tasks between multiple devices and applications (i.e., it will be necessary for other applications to adopt that task model in order to enable interoperability with MFW). The required cooperation to complete a forensic task will implicitly involve sharing

the collected data and the application, user and task contexts (see Section 3 for more information about these contexts). However, synchronization and context-awareness mechanisms have been designed to make those processes transparent to end users.

3. *The applications should explicitly recommend device and application changes to the user:* A rule-based subsystem will recommend the user when and why it will be necessary to change from one device to another. Currently, we are working on defining rules depending on the user location, user movements (moving around fast, being sit down, etc.) and available resources on each device.
4. *Continuous interaction:* Different mechanisms will be used to avoid disruptions while interacting with the MFW. For instance, we have been researching on methods to improve availability in ad-hoc networks [13], and middleware technologies to manage offline and online modes [14].

By adopting previous design principles, we expect that the workflow for changing from one device to another in MFW will become as simple as it is depicted in Figure 4, in contrast with the current workflow, which was depicted in Figure 2.

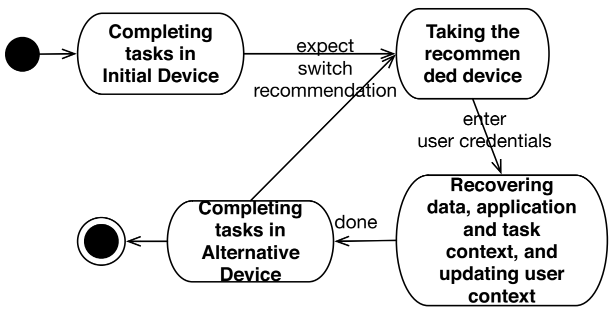

Figure 4. The expected workflow for changing from one device to another in MFW, depicted as a UML state diagram.

5. Related Work

In is common on research works related to ubiquitous, AmI and context-aware systems to make an explicit or implicit mention to the need of concurrently using multiple devices within the user environment [8] [6] [9]. For instance, the “Tangible Bits” paradigm [10] intends to translate reality into digital environments (or the other way round), potentially involving the use of many devices to complete even simple tasks. Adaptive graphical user interfaces have also been explored to increase usability and user satisfaction in scenarios with varying contexts in which several devices could coexist [11]. Moreover, in [12] it is mentioned the increasing parallelism of human thought (partially contributed by the new computing paradigms), which we think it will involve the concurrent use of multiple devices and applications.

The contribution presented herein intends to complement previous works by tackling with how the users will be able to manage multi-device, multi-application interactions without decreasing usability.

AMENITIES [5] has been taken as the conceptual model to figure out how to solve the usability problems that have been highlighted along this paper. That model has allowed us to understand that it might be necessary to leverage the concept of task even further than applications, files or other software abstractions.

For example, the notion of adaptive user interface is more focused on adapting specific applications to context variations. In contrast, in this work we aim at moving task execution to the most appropriate devices, depending on the user context, and even between multiple applications (i.e., understanding that the use of multiple applications might even be necessary, depending on the device).

In terms of technologies, several recent industrial contributions could enable the implementation of CoIn systems, taking into account the presented design principles.

Continuity (`https://www.apple.com/ios/whats-new/continuity/`) is a technology introduced by Apple in iOS 8 and OSX 10.10. It allows to transfer the state of a specific application to multiple Apple devices owned by the same user. The application can have different implementations depending on the device (iPhone, iPad or Mac computers), but they must be explicitly marked (through the appropriate software development mechanisms) to be the "same one" (i.e., the different implementations should have the same application name, same objectives, mostly the same functionalities and have to be developed by the same developers).

Continuity makes use of BlueTooth and Cloud-based synchronization services to offer its end user functionalities. In that sense, the improvement of the reliability and ubiquity of those technologies could improve the feasibility of implementing CoIn systems.

6. Conclusions and Future Work

This paper has introduced the notion of Continuous Interaction (CoIn) systems. These systems are aimed at facilitating user interactions with multiple devices and applications in order to complete a task. The idea is to benefit from the different characteristics that those devices and applications may offer to the end user: an improved content production, a better mobility, an easier content consumption, etc.

CoIn systems should be designed according to five design principles:

1. The task is the element to share, not the data.
2. Seamless completion of tasks by several users using multiple devices and different applications.
3. The applications should explicitly recommend device and application changes to the user.
4. Continuous interaction.

The Mobile Forensic Workspace (MFW) has been used as a case study to highlight the difficulties that end users may encounter while interacting with multiple devices within the context of an AmI system. The CoIn design principles are currently being applied to design a newer version of the MFW intended to overcome those difficulties.

As for future work, we plan to implement a new prototype of the MFW according to the new CoIn design, and evaluate its usability and perceived reliability. We also plan to propose a Platform-Independent Model (PIM) for CoIn systems, to make it more explicit their characteristics, inherent concepts and relationships between them. Finally, we will review the CoIn design principles according to the feedback obtained from end users and external researchers.

Acknowledgements

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Proceedings of the Symposium on Future Intelligent Educational Environments and Learning (SOFIEEe'15)

Editors

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Workshop Proceedings of the 11th International Conference on Intelligent Environments
D. Preuveneers (Ed.)

doi:10.3233/978-1-61499-530-2-95

Introduction to the Proceedings of SOFIEEe'15

As the world moves steadily to become a knowledge-based economy, education and learning have never been more important. Technology is playing an increasingly crucial role in the delivery of education, which in turn is driving research into the search for ever better technological solutions. The age of intelligent environments is bringing such pedagogical advances as smart classrooms, intelligent campuses, immersive and mixed-reality learning, affective learning, mobile learning, intelligent learning clouds and personalised intelligent tutors to revolutionize current learning practices, and to challenge the traditional notion of a university or school.

Based on this context we launched the 1st International Workshop on *Future Intelligent Educational Environments* during IE'12 in Guanajuato (Mexico) and we decided to continue this event with the hope this will provide a forum where to discuss the current state-of-the-art, imagine solutions for current limitations and plan steps within our community which may help to achieve some of the required advances in this area. This year the event has joined efforts with the *Shanghai Education Forum*, which was run as part of IE'14 in Shanghai, to create the Symposium on *Future Intelligent Educational Environments and Learning 2015 (SOFIEEe15).* This event will serve as a forum for researchers and practitioners to discuss the latest intelligent technologies that can support the development of new educational technologies and environments around the world.

Central to this forum are enriched physical and virtual environments such as smart classrooms, virtual / mixed-reality environments, intelligent learning clouds or mobile and augmented-reality systems that can interact with students and teachers at a pedagogical level, so as to bring true innovations to education. We also include the systems that support the learning of practical skills, such as those typified by science and engineering laboratories that are critical to students. We also consider the wider campus infrastructure, which can also impact the cost and effectiveness of education. Examples include smart signage that can guide people around a campus or smart applications for timetabling or managing the environment of the teaching facilities. Education is increasingly global and the cultural dimension is a topic we consider important for this event. Finally, scientific research, engineering Innovation and business advancement are beneficiaries of good education and it's fitting that we are including a paper that considers how entrepreneurship for creating and commercialising future educational environments might be supported.

As a final note, we wish to express our sincere thanks to the SOFIEEe'15 Program Committee for their thorough reviews and strong support. We will also like to acknowledge our gratitude to the authors who submitted their contributions and to those who will be there during the event to enrich the event with their opinions. We are looking forward to meeting you all at this workshop which will allow us to meet and build a strong community dedicated to introducing exciting innovations to education.

Minjuan Wang, Juan C. Augusto, Vic Callaghan
Co-chairs SOFIEEe'15

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Error Analysis Expert System Based on the Takagi-Sugeno Model

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Abstract. The error data obtained from the front-end in-class feedback system would be analyzed and judged by the back-end expert system, and the causes of such errors would be provided and the corresponding after-school exercises would then be automatically pushed to the students by the cloud service platform to increase targeted learning and learning efficiency.

Keywords. expert system; Takagi-Sugeno; Cloud Computing; education; SOA.

1. Introduction

How to improve teacher's targeted teaching and students' enthusiasm and initiative for learning is one of the key issues needed to be addressed during the process of teaching and learning. "Electronic Classroom" and "Physical Studio", popular in America where students are required to think and answer all questions through the man-machine dialogues during the learning process, provides us with good examples. Experiments conducted on the use of "electronic school bag" and the computer-aided teaching and learning through cloud computing technology, undertaking in some districts of Shanghai, prove that student's workload can be greatly reduced and their learning efficiency can be enhanced with the help of the aforementioned technologies. In 2009, a study on the use of the educational cloud service platform was launched and the main content is summarized as follows.

2. Content of study

1) To increase the interaction between "cloud" and users through the collaboration and sharing of teaching resources. All lecturing slides, in-class exercises and some other related documents of each class are required to be uploaded to the cloud platform, and teachers can re-edit the resources downloaded from the platform and make them a tailored-made version of their own. To achieve such aim, standards of teaching resources need to be established to ensure their effectiveness and being up-to-date.

2) To create an integrated cloud service platform where teaching and learning data can be automatically collected, intelligently processed and analyzed and effectively

applied. Through lightweight, user-friendly cloud computing configuration and the client program, a process-based evaluation system on education quality can be established with the involvements of various stakeholders.

3) To create a student-centered cloud service platform where services such as learning through animation and exercises re-practice can be pushed according to the student's wrong question list. A virtual rewards and credits mechanisms can be adopted to improve the motivation of learning, helping students to establish good learning habits.

4) To adopt a blended learning model which combines online learning and offline school education to help students to obtain knowledge.

5) To solve the inequality in compulsory education from the technical level. By using the educational resources from key schools and senior teachers, the growth process of young teachers can be shortened, and the gap between key schools and non-key schools can also be narrowed.

3. Technology Solution

3.1. Architecture of the platform

The architecture of the platform is shown in Fig. 1. The system structure is divided into four layers, namely infrastructure layer, data layer, support layer, and business layer. The technology plays a central role in the data layer and the support layer and an open and sharing platform was built, while business transaction plays a central role in the business layer and different business systems can be realized in that layer [1].

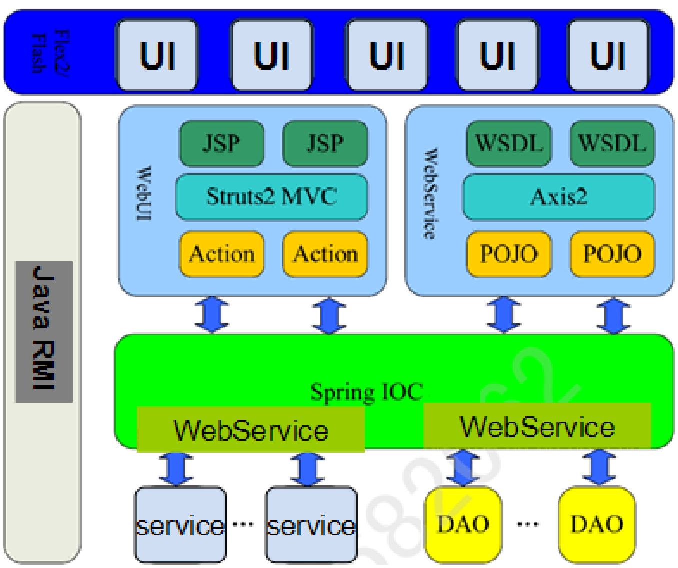

Fig. 1 Architecture of the platform

3.2. Expert system based on Takagi-Sugeno

The expert system [4] is shown in Fig. 2.

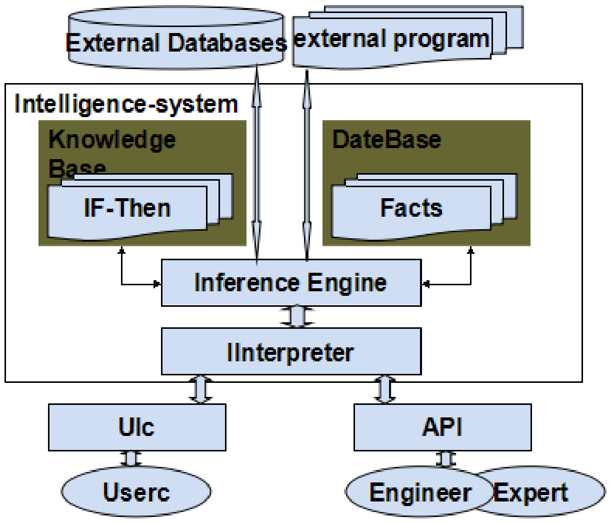

Fig. 2 expert-system

T-S system, composed of N follows rules
Ri: If s_1 is L_1^i and s_2 is L_2^i and … And s_n isL^i_n
Then y^i = pi 0+ pi1s1 + … + pinsn
s_1 ,… , s_n as the input variables, y_i as the I rule consequents output variables,Li^1 ,… , Li^n as the triangle membership function,pi 0 ,… , pin as linear gain.

Output for T-S system ,As the activation rule consequent weighted sum.

$$y = \sum_{R_i \in A} [\sum_{j=0}^{n} p_{ij} s_j] \tag{1}$$

TR^i as the rules of the true value, A as collection of all activated rules, s0≡ 1.

4. Model design

A four-in-one teaching and learning platform for students, parents, teachers and schools is established and is shown in Figure 3.

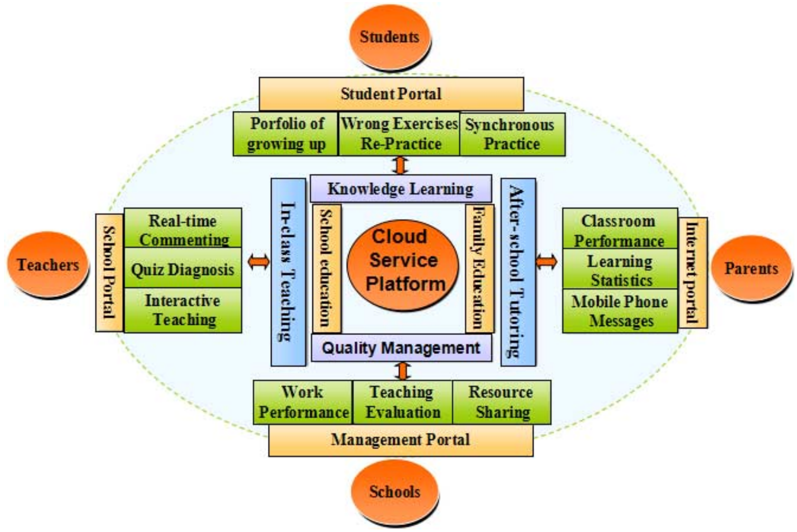

Fig. 3 the Four-in-one teaching and learning platform

Business model is shown in Fig. 3.

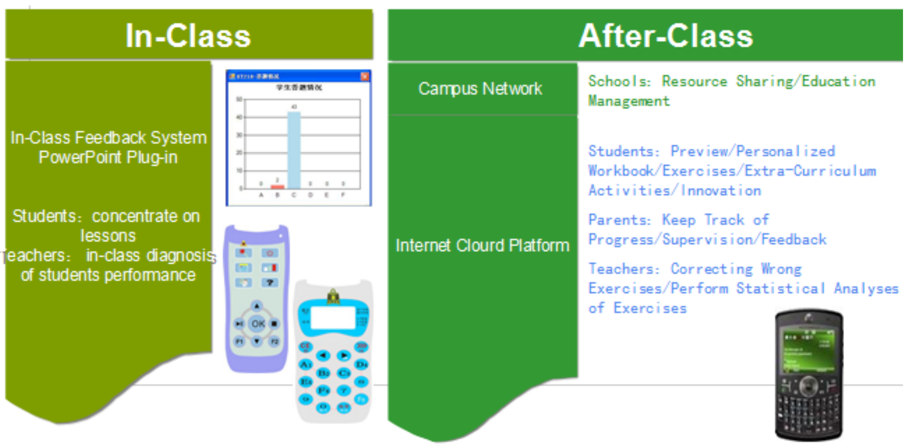

Fig. 4 Business Model

Teachers, students, schools and parents, which respectively correspond to different busisiness functions. [4]

Teachers' individualized teaching:

- Using through PowerPoint Plug-In
- Teaching with Animation
- Controling the rhythm of the class
- Attracting student's attention
- Checking the missing or
- Performing After-class statistics analysis
- Undertaking individualized teaching

Students' Learning on demand:

- Preview lessons with animation
- Concentrate on study
- One-to One education
- Personalized wrong question lists
- personalized exercise book
- Publishing personal work
- Peer communication
- Immediate reward with credits and virtual pets
- Preview
- In-class exercises
- After-class review

Schools' Sharing Resource:

- Sharing high-quality resource
- Managing with quantitative standard
- Increasing teaching efficiency
- Ensuring the education quality
- Promoting overall quality of students

Parents' Keeping track of the whole learning process:

- Keeping track of learning progress
- Keeping track of learning target
- Keeping track of learning process
- Keeping track of path of growing

The metadata model for an on-demand teaching and learning is shown in Fig. 5.

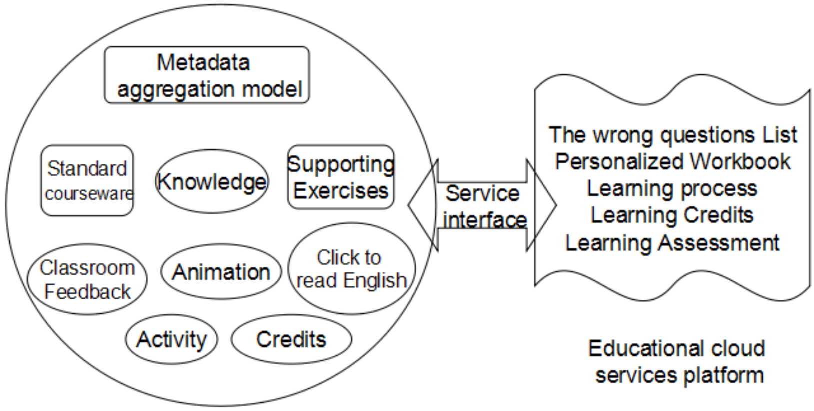

Fig. 5 Meta data model

Meta data model has two sides：the on-demand teaching and on-demand learning.

1) On-demand Teaching

According to the results from the in-class feedback system and the effect of student's learning, follow-up teaching materials can be downloaded from the cloud service platform and be re-edited to support personalized teaching.

2) On-demand Learning

In accordance with the result of in-class interactions, a wrong question list and a personalized workbook can be created and only exercises that aim at correcting those wrong questions need to be practice again. In this way, the traditional exercise-stuffed teaching methods can be break, and the workload for homework can be released. Meanwhile, through the credits and virtual rewards mechanism provided by the cloud service platform, students' enthusiasm for learning would be greatly encouraged, and good learning methods and habits would be developed. [3]

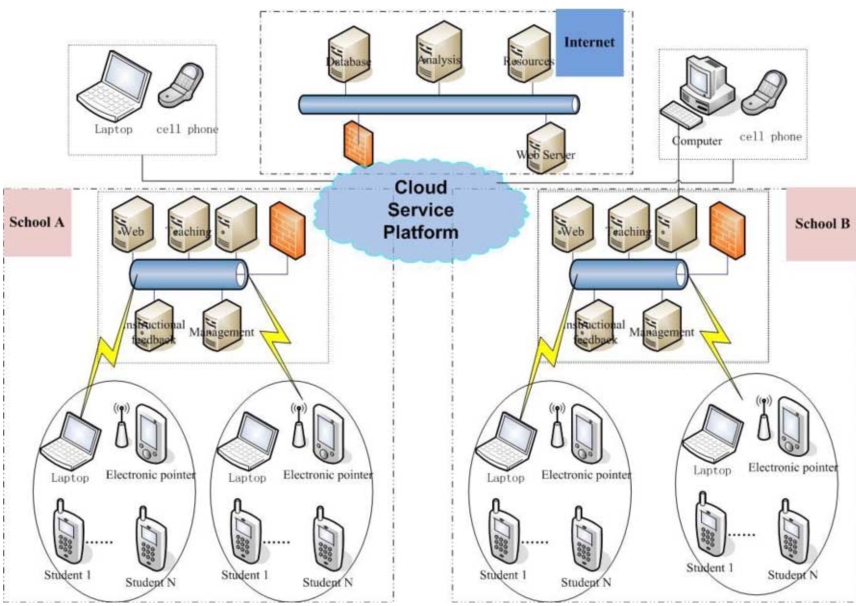

Fig. 6 the topological structure of the cloud service platform

A cloud computing-based distributed architecture with RUP methodology was adopted for the educational cloud service platform. The topological structure of the system is shown in Figure 6. Based on the service-oriented architecture (SOA) the platform can be adapted to the students' new learning methods and learning content, and can also be adapted to the new requirements from parents and teachers. The characteristics of the platform can be summarized as follows:

1) In accordance with the characteristics of cloud computing technology, networks, systems and equipment are transformed into "Infrastructure as a Service (IaaS). Students can not only obtain the quality educational resources of the region, but can also freely access the cloud pool to obtain resources on demand.

2) Through the cloud computing technology, targeted learning services for students would be pushed according to the profiles of students development, students’ need can be understood and their curiosity can be fully stimulated. [2]

3) Through the cloud service platform, comprehensive and dynamic services which integrated the need of teachers, students, parents and schools can be provided to students. Related stakeholders can be tightly linked together and targeted strategies can be provided for students’ overall development.

5. Implementation

In September 2011, the cloud service platform was firstly used in the six selected classes in Zhuhai No. 1 primary school. After one semester, teachers, students, parents, and school management were satisfied with the experimental results.

In February 2012, the above experiments were extended to 24 classes and then 48 classes later in September 2012. The total student number of the primary school is 2442, while the total number of teacher is 127. Up to present, 1930 classroom lecturing slides have been uploaded, while the downloads reached 32897, and with a total visitor of 37831.

From the result of the experiment, stakeholders can gain benefits from the use of such cloud service platform, in the following ways:

5.1. Tailor-made lecturing materials and individualized teaching

From the teacher’s point of view, based on the learning feedback of students, materials downloaded from the public teaching database can be re-edited and then such personalized lecturing materials can be uploaded to a personal folder for later use. With such tailor-made resources, individualized teaching can be carried out, and the teaching effectiveness can be increased. [5]

5.2. Personalized and autonomous learning

From the student’s point of view, through in-class interaction, students' attention is concentrated, the weakness of each individual student is identified, and the result of classroom teaching is uploaded in real time to the service platform. Services such as learning through animation, exercises for wrong question list would be pushed for after-class re-practicing. In addition, the platform can be used as a online showcase for personal or team projects and the communication between students can be strengthened through peer evaluation. The virtual credit and reward mechanism encourages students to work hard and develop good learning habits. [6]

5.3. School Quantitative management

From the school administrator’s angle, with the platform, the teaching data of each class can be analyzed real-time and targeted guidance can be provided to improve the quality of teachers.

5.4. Resources sharing

From the view of the education management institutions, the results of the teaching can be analyzed and the real-time teaching resources of local schools can be allocated and managed and the high-quality teaching resources can be pushed to the poor and backward areas to promote the common development of education.

5.5. Parent's real-real information

Through SMS and the cloud service platform, parents can be informed of student's real-time performance in school, and targeted counseling can be provided for students after class. Such interaction not only improves the efficiency of student learning, but also strengthens the parent-child communication.

After more than one year implementation of such pilot project, the result of a 30% reduction in the teachers' workload and a 50% increase of students' enthusiasm for learning and target learning can be achieved. Fewer students suffered from learning difficulties and the feedback cycle of parents can be reduced from two weeks to daily acknowledgment. School management's quality evaluation can be performed daily rather than waiting to be carried out at the end of the semester. Feedback from students, parents, teachers and schools is satisfactory. Show in table 1.

Table 1：comparison before and after experiment

Teacher: Xue Ying	Fill in date: Dec 28th, 2012	
	traditional model	cloud service platform
time for in-class exercise	15 minutes	10 minutes
number of exercises	10	20
student's involvement in exercises	70%	100%
time for teacher correcting exercises	40-60 minutes	1 second
average error for correcting exercises	3%	0%
period for teaching and learning outcome	2 days	1 second
resources sharing between parents and schools	0%	100%
period for exercises analysis	2 days	1 second
period for student correcting exercises	3 days	1 day
percentage of targeted exercises practice	50%	100%
period for parent's feedback	15 days	1 day
period of teaching quality management	1 month	1 day
student's initiative for learning	general	strong

student's burden for learning	general	general
teacher workload	heavy	50% less

6. Summary

The four-in-one educational cloud services platform was established to increase targeted learning and learning effectiveness. With the help of the latest cloud technologies, on-demand teaching and learning can be realized, and parents and school managements can be actively involved in the teaching and learning process.

However, the implementation of cloud service platform needs to be a huge systematic project. Through continuous improvement, more schools would be attracted to join the pilot project and the allocation of resources would be optimized, narrowing the gap of education quality between the developed areas and underdeveloped areas.

Acknowledgements

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A Study on a Solution of Education Inequity in Chinese Rural Schools through Live Broadcast Classroom

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Abstract. Inequity between urban and rural education prevalently exists in China. Lack of qualified teachers is the main cause for disadvantaged education in rural area. In order to solve this problem, Live Broadcast Classroom was adopted in grade 5 English class. 90 students and 3 teachers of 3 classes from two primary schools in Yunnan Province were selected as participants. As for methodology, quantitative and qualitative methods were used. Results showed it was feasible to use Live Broadcast Classroom in solving the inequity problem in micro-level education (i.e., classroom): the gap between students' scores and attitudes towards English between urban and rural classes was narrowed. Challenges still exist and some suggestions are put forward in the end.

Keywords. Education equity, Live Broadcast Classroom, English attitude and score, Interaction design

1. Introduction

Basic education equity is an important part of social justice. As proposed by the Welfare Economics, the equity of personal predisposition is a prerequisite for the equity and maximization of social welfare. Moreover, a considerable number of empirical studies have shown that education inequity will enlarge the income gap in a society, impairing economic development in turn [1]. Education equity is an urgent issue all over the world. The 2010 Monitoring Report on Global Education by UNESCO (United Nations Educational, Scientific and Cultural Organization)[2] pointed out that, in the poorest countries, the global financial crisis is threatening millions of children's chances to receive education, which will depreciate overall achievements in a society. Therefore, inclusive education was proposed to alleviate the education inequity, as well as eliminate social injustice.

With the full implementation of the compulsory education policy in China, the goal of every child going to school has been basically achieved. However, there is still an obvious gap in education quality among regions, rural and urban areas, as well as among different schools. Contradictions exist between the demand and the supply of quality education. To promote the equity of education has become the priority in the compulsory education in China according to "further deepen reform and make balance of compulsory education", a policy of the State Council [3].

2. Theoretical framework

Education inequity exists widely in China, because imbalance of supply of qualified teachers in rural areas. LBC may provide a solution for it. Therefore, the following section will review the literature of education inequity and LBC.

2.1. Definition and categories of education equity

Education equity was first coined by American philosopher John Rawls. Rawls argued that equal opportunity in an education system has three principles: first, providing equal education support for those who are qualified for education; second, providing ultimate education for everyone; third, providing special education support for disadvantaged groups [4]. Based on these three principles, Farrell further put forward three main equity forms to school education, including opportunity equity, input equity and result equity [5][6]. Besides, Farrell and other scholars pointed out that education equity has several different dimensions, for example, race, ethnicity, socioeconomic status, gender and geographic location. [5][6][7][8][9].

As for the categories of education equity, there are three levels: the macro level, medium level and micro level. The education equity of macro level refers to every child's equal right and opportunity to receive education from a personal perspective, as well as harmonious development among education, economic and social development from a social perspective. Macro equity is mainly reflected in policy and education institutions associated with education rights, opportunity, scale, and structure. Education equity at medium level includes equity among different areas, schools, and groups, such as school equipment and areas. At the micro level, education equity lies in the equity of curriculum, instruction and evaluation, which influence students' performance in a classroom [10]. The first two levels of equity involve the education policy and resource allocation, which are able to influence the micro level equity, and at the same time, are embodied by it in a specific classroom.

In general, these different levels of equity are able to cover whole educational processes: input equity such as education opportunity and resource allocation, process equity in teaching and learning, as well as the output equity of students' learning performance and enrolment.

2.2. Indicator of education equity

Based on the above categories, measurement of education equity could be used to indicate the degree of education equity. When it comes to education opportunity, students' enrollment rates are often utilized between urban and rural areas, or men and women. As for education resource distribution, some indicators could be used, such as public education funds, average budget per student, average school area per student, classroom equipment and qualified teachers. When it comes to the process and results of education equity, the ratio of students' graduation, dropout and enrolment are often used. Moreover, students' performance is an important indicator for output equity [10].

2.3. Inequity of basic education in China

In China, the gap between rural and urban schools is the main contributor of basic education inequity [11]. With "the planning outline of national medium and long-term education reform and development (2010-2020) "released and practiced, China has made great progress in promoting the equity in basic education—education accessibility, resource distribution, education process and education results tend to be the most equal that they have been [12]. However, the education inequity between rural and urban areas has the tendency of intensification. The urban population has 13 years of education on average, much longer than the rural population with an average education of 7 years. Besides, urban students have the privilege of selecting better school for themselves, but the peers in rural areas have no other choices. Moreover, rural students have to leave home and live in the central school far away from their homes, thus losing parents' tendance that should play an irreplaceable role for students' growth [12]. Following are the specific causes behind the inequity of rural and urban education [11].

2.3.1. Inequity of education funds

There is a huge gap of average funds for students in K-12 schools between the urban and rural areas. Although the budget allotted to rural schools by the government has increased a lot, and the ratio of education budget between urban and rural of primary schools has gone down from 1.91 in 2005 to 1.18 in 2008, but the gap between urban and rural secondary school tends to rise, keeping the same ratio from 2005 to 2007, but going up to 1.78 in 2008 [10].

2.3.2. The differentiation of education opportunity

Urban-rural school segregation has put rural children in a disadvantaged situation from the starting point. The data shows that about 80% of the rural school-age population doesn't have a chance to participate in the College Entrance Examination, because of the poor quality of high school education in rural areas. The more serious inequity lies in the enrollment of higher education. In 2003, gross enrollment ratio of Beijing higher education for local students is 49%, while only 8.64% in Yunnan province. In addition, the enrollment number of rural students for top universities is decreasing year by year [13].

2.3.3. The gap of school selection ratio between urban and rural areas

School selection is for those who are not satisfied with the original arrangement to choose other suitable schools. Selecting a proper school for students embodies the right and freedom of education. It is different for rural and urban students as well. The ratio of primary school selection in a city was 4.8%, 3.3% in county primary areas, but only 2.0% in rural primary schools. The ratio of middle school selection in a city was 9.8%, 6.3% in county, only 3.1% in rural middle schools [11]. For rural students, who have no other choices but to stay in central school far away from their homes, have little choice to change. By contrast, the school selection rate is high in the city where there have been more high quality resources and schools available for students to choose.

2.3.4. Inequity of teacher quantity and quality

Both the quantity and quality of urban teachers is better than rural teachers. In the city school, all disciplines have corresponding professional teachers to teach each subject, but in rural schools, because of a serious shortage of teachers, teachers have to be responsible for different disciplines and scores beyond what they have learned. For example, some teachers without background in music are teaching music, the same with others such as information technology, sports, English, and arts in rural schools. In addition, the ratio of excellent teachers in rural schools is much less than urban schools. What's more, some teachers in rural schools are not formally hired by schools. According to the statistics, there are 499,000 non-contracted teachers concentrated in rural primary schools in China, 75.9% of which are distributed in rural primary school in the central and western China. These teachers, with poor allowance, barely devote themselves into education.

At the aspect with the teacher's quality in rural schools, the gap between urban and rural schools is also huge. The study showed that, in 2005, the ratio of the teachers with associates or above is 78.01% in primary schools in Chinese urban areas, still 31% higher than that in rural areas. The ratio of the teachers with bachelors or above is 62.44% in urban areas and 38% higher than rural areas [13].

2.3.5. Dropout of rural teachers

Due to the disadvantageous location and economic conditions, it is hard for rural schools to attract talent to work there. If possible, teachers in rural schools would look for any way to leave rural areas and move to urban areas. The ways include becoming indispensable teachers or having the higher position in school.

2.4. Using Live Broadcast Classroom to solve the problem of education inequity.

To solve the problem of poor quality and quantity in rural schools, on-site training alone is not enough. The development of information technology to solve the problem of education inequity may open a new way, whereby quality resources could be shared across areas with low cost, convenience and efficiency [3]. Through the program of "disadvantaged school reform project" and "resources sharing for the whole" funded by the Chinese government, there have been a great change in the establishment of quality resource database, and live Broadcast of good schools. However these resources, although suitable for students in urban schools, are not tailored to rural students growing up in local culture and circumstances. To promote education equity with information technology, adjustment to suit the local situation is needed [14].Live Broadcast Classroom (hereafter referred to as LBC) across the same cultural schools in a county may be an alternative to not only share quality resources, but consider the local culture and situation.

2.4.1. Definition of LBC

LBC is used to transfer a high quality class to distance classes via satellite or internet. In particular, LBC uses video cameras recording teachers' activities in one classroom and then the recorded data stream is broadcasted to another classroom. Therefore there is a short transmission delay, but synchronized discussion among several classrooms is possible. [15].

2.4.2. The advantages of LBC

According to the summary by Wang and Gu, the LBC has many technical advantages, such as a wide geographical coverage, low cost, speed and convenience [16]. So we can try to use it to partly solve the inequity in education, particularly the shortage of quality teachers in rural schools, with updated lectures shared by teachers from better schools, but with same cultural background in one county. That also lessens the economic and management pressure of rural schools to purchase and maintain equipment.

2.4.3. The researches on LBC

There has been little empirical research on LBC experiments, although in China the experiments have been done in a large number of schools. For example, the 7th Middle School in Chengdu city has been broadcasting live class activities to hundreds of schools since 2002. However, except for some descriptive studies on how to design [16] [17], develop [18] and manage LBC, only one study was conducted to examine its effect on students' performance. It was found that LBC was just effective for those students with the same level and background in both sides. That is to say, if one student in a rural school is as excellent as another student in an urban school, the rural student would be greatly enhanced in his/her math and physics scores. For the rest with poorer starting points, the result is not positive, and even worse. Except for scores, other indicators such as learning motivation, learning ability, psychological health and understanding are also improved little.

More positive results are from rural teachers, more than 80% of whom in rural schools admitted that they had developed profession through learning how urban teachers designed and developed curriculum. Besides their information literacy has been greatly enhanced [19].

2.4.4. The problems exists in LBC

First, the serious shortage of interaction weakens the effect. Due to one-to-many distance teaching mode, it is hard to communicate effectively between the input class and the output class particularly among teachers and students on both sides.

Second, it is difficult to make education inclusive for all students whether they are excellent or not. As shown in the study Chengdu's LBC, only outstanding rural students could benefit from LBC, and students with ordinary or poor learning foundation found it difficult to adapt to it. That is contrary to the core of education equity where every student should benefit. In the rural areas of western China, the majority of students have poor starting points and learning foundations. It is necessary to rethink LBC and design curriculum content and method tailored to rural students in general [19].

In this study, we tried to design rich interaction to solve the problems of poor interaction and chose students with the same culture and background within the same county. Finally we analyzed scores and learning attitudes for all students, and whether the gap between both had shrunk.

3. Study design

3.1. Participants

This study was conducted respectively in Guangnan No.2 Primary School in Guangnan County, the best local school, and Ake Primary School in Bamei Village, the most disadvantaged local school. Both schools are located in Wenshan Prefecture, Yunnan

Province, which has the most disadvantaged schools in China. They are extremely short of professional teachers, especially qualified English teachers. Therefore, English has been canceled in some schools.

In this study, 60 students from two Grade-5 classes and two female English teachers were selected in Ake Primary School. One teacher, 32 years old, has 7 years of English teaching experience (hereafter referred to as Teacher A, and her class referred to as Class A). Another teacher is 39 years old and has taught Chinese for 19 years, without any English knowledge (hereafter referred as Teacher B, and her class referred to as Class B). 30 students from Grade 5 and one professional English teacher (hereafter referred to as Teacher C and her class referred to as Class C) in Guangnan No.2 Primary School were selected. The 36-year-old female teacher, with 19 years' English teaching experience, served as the broadcast lecturer in this study. In all the three classes, the ratio between male and female students is 1.1:1, and the average age is 12 years old.

3.2. Research questions

In this study, we will explore the questions below:

- How should the lecturer teach in LBC?
- What is the effective interaction pattern in LBC for primary school English?
- What is students' general attitude towards LBC?
- Did the instructional design above narrow the gap of students' English attitudes and scores between both sides?
- What questions should we pay attention to in LBC?

The first two questions aim to explore how to interact and teach in LBC; the middle 2 questions are the effect caused by LBC; and the last question is for possible difficulties or problems in LBC.

3.3. Research Methods

Research methods should correspond to the research questions. The study involves design of teaching process and interaction between students and teachers, as well as the questions we should pay attention to. Thus we mainly use the design method and quantitative method.

With the method of Design Research, researchers would collaborate with practitioners in analysis, design, development, and implementation of strategies in a real situation to improve the education. Then researchers would abstract principles and theories based on this kind of context sensitive design [20]. The design part of this study also has the goal to build the teaching Process Model and Interaction Model in LBC.

In terms of the evaluation of students' learning performance and attitude, we adopted the quantitative method. In particular, we mainly used the Scale of English learning attitude to examine students' English attitudes, which was developed by Han and Xu and had undergone large population test and some modification. This scale was divided into five dimensions, which respectively covered English language attitude(1,2,3,9,10), learning attitude(4,5,11,19,25), teaching attitude (6,12,13,24), learning objectives (7,8,15,16,17) and learning motivation (14,18,20,21,22,23) [21]. The validity and reliability of the Scale's structure is reasonable. The reliability coefficients of Cronbach about the total table and the subscales are above 0.70. For students' scores, we chose the local exam content as the pre-test and post-test to check the gap between both sides.

Besides, interview and class observation were conducted to understand the problems or obstacles faced by the teachers and students in LBC.

3.4. Research process

The period of this research was one month. First, we examined 90 students' English attitudes and knowledge before the intervention of LBC. At the same time, teachers participating in the study were trained to be familiar with LBC and try to cooperate in teaching the two sides of students.

During the experiment, the researchers and tutors organized both sides' teachers to design classroom activities, have lessons together, and reflect on what should be modified in next time. In general, the urban teacher took the main responsibility for teaching and learning, while the rural teachers mainly facilitated the rural students to understand and interact with the urban teacher.

At the end of the experiment, all the students were tested using a learning attitude scale and knowledge test. We also interviewed the students and teachers respectively to know the general attitude towards LBC.

4. The results of the study

For this part, we aimed at answering research questions, including the design of teaching process pattern and interactive pattern in LBC, the learning effects of students, the problems faced by the teachers and students in LBC, and further putting forward suggestions to LBC.

4.1. The model of LBC

We designed and used four kinds of synchronized activities for both sides' teachers: synchronous design of activities, synchronous lessons, synchronous exercise and synchronous reflection (as shown in figure 1).

4.1.1. Synchronous design of activities:

In this part, curriculum experts cooperated with the teachers of both sides in terms of analysis of students' initial knowledge and skills, learning interests and correspondingly designing appropriate curriculum and teaching strategies. Besides, interaction among teachers and students were considered according to teaching strategies.

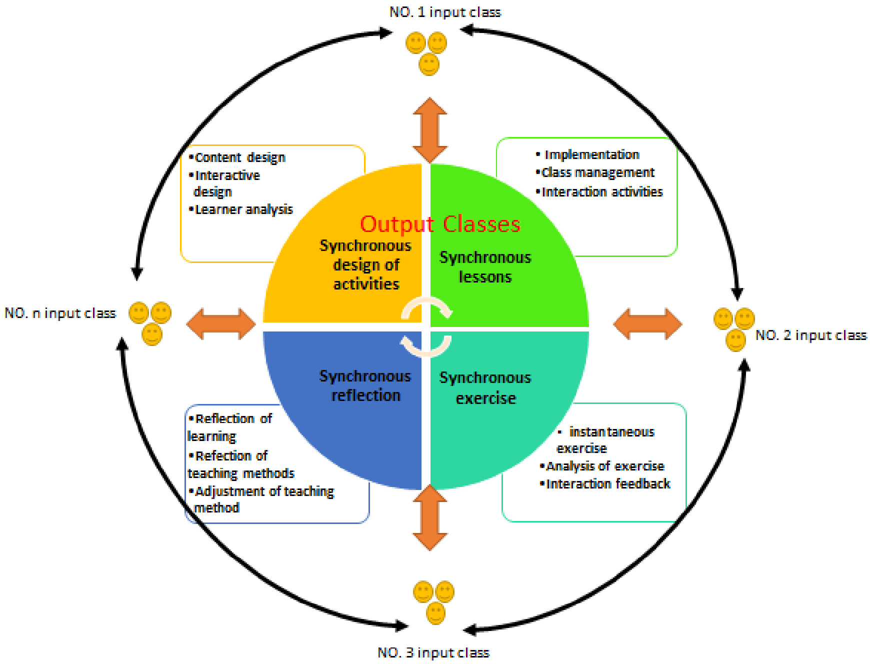

Figure 1 Synchronous model in LBC

4.1.2. Synchronous lesson

The urban teacher played a primary role in LBC. In particular, she logged in the LBC system as the administrative teacher, with priority to open new lessons, to share teaching materials with remote rural classrooms, to pose questions for all students, and to organize interaction among students. At the same time, rural teachers took responsibility to remedy what students were not clear up and help to manage students' activities in the rural classrooms. During this process, the urban teacher would adjust teaching strategies and pace according to students' immediate feedback from local classroom and live video flow of rural classrooms.

4.1.3. Synchronous exercise

Given synchronous exercise, students had the chance to apply what they learned to practical problems, and more importantly, the reaction of students could give teachers instantaneous feedback so as to adjust teaching pace and strategies to meet the students' needs in time.

4.1.4. Synchronous reflection

After class, the teachers of both sides would reflect what should be adjusted to fit students in terms of content, teaching strategies, evaluation, and interaction. The teachers should form at the reflection into a document, facilitating the teachers of both sides with reference for cooperative preparation of class next time.

4.2. The interaction pattern of LBC

We mainly designed two kinds of interaction of LBC.

4.2.1. The synchronous interaction among students.

The urban teacher organized the interaction for both sides, including two ways: voice interaction in turn and text interaction on the whiteboard synchronously in different classrooms. Except for remote interaction, local interaction separately in the same classroom may happen.

- The voice interaction in turn: The urban teacher organized the students in each class to answer the questions in turn;
- Text interaction of different whiteboard on both sides: Students in different classrooms could type text on their own electronic whiteboard, see each other's typing remotely, and evaluate it at the same time.
- Local interaction among students: It is the group discussion or experience sharing activities respectively among the students in the same class.

4.2.2. The interaction among the teachers (input class and output class)

This is the interaction among both sides' teachers for confirming questions to be understood by students and facilitating students to solve problem.

Based on the design of LBC and interaction aforementioned, both sides' classrooms had been entering a shared learning space. The following part will show the effect of LBC: Has LBC solved the problems of lack of teachers? Has the gap between rural and urban students shrunk after the experiment? Next, we tried to analyze the learning effect from three aspects: students' perception of LBC in both side classes, comparison of pre-test and post-test in learning scores and the change of learning attitude towards English.

4.3. The general attitude of these teachers and students towards LBC and interaction design

The students' perception of LBC is very complicated.

4.3.1. The students' attitude towards LBC is mixed

The urban students in output class and rural students in input classes generally believed that to communicate with each other in different classes is a "cool" thing, especially writing whiteboard of different places. Moreover, the voice interaction between different classes made students feel "fantastic" and "entertaining", but sometimes they need courage of "daring to do so" because they felt nervous and shy if "my answer is not good, I will feel ashamed, especially facing strangers". However, compared to communicating with other classes in different place, students preferred to communicate with each other in a local place, "because we're all familiar with each other, there would be no embarrassment when our answer is wrong".

4.3.2. The rural students' perception of LBC is more positive than urban students

The rural students were likely to cherish the opportunity more to interact with students outside their schools. From class observation, rural students were more active than urban peers, with more frequencies of writing and voice interaction with others. It was confirmed in the later interview in which they said, "we could get insight a lot by communicating with the urban students who should have the broader perspective than us".

4.3.3. Teachers hope to have more cooperation.

Firstly, Teacher B learned much in LBC, not only in English teaching methods, but also in English content. Being excited about LBC, she wanted to continue to take part in similar activities in the future. Meanwhile, she also hoped that Teacher C can repeat or express her instructions more clearly when her students couldn't follow, since she was unable to make herself understood. Secondly, it is impossible for Teacher C to manage the three classes at the same time, Teacher A and B should coordinate with Teacher C to carry out instructions effectively. Thirdly, Teacher A was quite experienced in English teaching and she didn't think LBC benefitted her much. She even put forward suggestions for improvement in terms of instructional design and class management. However, her suggestions were just partly accepted by Teacher C. So she thought that there is the need for more in-depth cooperation. In general, these three teachers should further their cooperation from different perspectives.

4.4. The gap of English learning attitude between output and input classes disappeared

In terms of English attitude, there is no significant difference between Class A and B before the study. However, there is significant difference between Class C and Class A in English learning attitude ($F=2.46$, $P<.01$). This shows Class C had more positive attitude than Class A. As for attitude towards English teaching method, Class C is much more positive than Class B ($F=2.13$, $P <. 05$).

After the intervention of LBC, there is no significant difference in all dimensions of English attitude among the three classes. It demonstrates that LBC enhanced Class A and Class B students' English attitudes so that the gap of English attitude among the three classes disappeared.

We also interviewed the students in the three classes. This showed that even though a few students still had negative attitudes towards English, the majority of students have fostered more positive attitudes through intervention. They commented that before the intervention of LBC, their English class was so boring because of the lack of communication and activities. "Although English is very useful, I dislike English class most compared with other subjects, because it is too difficult and boring". "I like to learn English in LBC, because interaction is more frequent, and games and activities are employed". Some students even thought it not difficult to learn English any more.

This suggests that LBC is effective in narrowing the gap of English attitude among the three classes.

4.5. The gap of English scores among the three classes was narrowed

In the pretest, the scores of Class C were significantly better than that of Class A and B ($t=2.7$, $P<.01$), whereas there was no significant difference between Class A and B. Then Covariance Analysis was done with the pretest scores as covariant variables, and results showed that there was no significant difference among the three classes.

The study indicates that LBC narrowed the gap in scores between Class A, B and C. The result is not consistent with the study in No.7 Secondary School of Chengdu Live Classroom in which only outstanding students' scores in rural schools had been improved.

It is noteworthy that there was no significant difference between Class A and B in both pretest and posttest. Even though the professional English teacher was not available for Class B, the students still made the same progress as Class A in their scores through LBC. This implies that LBC could alleviate the pressure resulted from the lack of professional teachers in rural schools.

4.6. Challenges facing LBC

Although LBC narrowed the gap of learning attitude and scores between rural and urban students, it still had some challenges to face.

4.6.1. Too much workload for Teacher C

The interview showed that Teacher had too big of a workload. For instance, she had to give instructions as clearly as possible, manage activities among the three classes, take their feedback, and collaborate with other teachers. “I was so tired that I forgot my pace”, said Teacher C, "if the salary is not increased, I won’t continue this kind of class". This suggests that LBC involves support from the educational administration to balance the workload and income of relevant personnel.

4.6.2. Lack of classroom facilitation

Class observation revealed that Class A and B can hardly follow the instructions from Teacher C, so Teacher A and B need to repeat, highlight and explain key words in time, as well as organize activities in their own classroom. However, the teachers didn’t meet these needs, which led to a waste of time and low efficiency.

Besides, during interaction related to writing on the whiteboard, students also need technical help from their teacher, otherwise the classroom would be in chaos and the pace of instruction would be interrupted.

4.6.3. Poor integration of information technology into curriculum

LBC involves related hardware and software such as the Video System, the Whiteboard System and the Live Broadcast System. However, class observation showed that the teachers were not familiar with the whole system so that they often spent more time in making the system work and barely facilitated learning well. Therefore, training is necessary for participant teachers to integrate technology with curriculum effectively.

4.6.4. Low efficiency of interaction

Firstly, due to limitation of the Internet bandwidth, data transmission was sometimes delayed, and information was partly distorted. Highly dependent on the Internet, interaction among the three classes was affected by the delay and distortion of information.

Secondly, the large number of students (90 students in total) decreased the efficiency of interaction, especially in voice interaction. As was shown, when a student presented, the waiting time of other students lowered the efficiency of interaction.

Based on the aforementioned challenges, suggestions were put forward as follows.

5. Suggestions for LBC

The following section will discuss suggestions from two perspectives: design and implementation of LBC.

5.1. Suggestions about the design of LBC

5.1.1. Take student's level and culture into account

There can be some gap of student's level and culture between urban and rural students, since it is necessary to carry out activities in LBC to share quality resources. However, the gap should be reasonable so that rural students could follow the pace of the instruction. This is verified in the present study in which all the students of Class A and B benefitted from LBC, while the study on Chengdu No. 7 Secondary School was just effective for outstanding rural students, because of the huge gap between different classes.

Therefore, student's level and culture should be taken into account before the design of content, interaction, and the synchronous instructions. Measures can be taken to acquire information about the student's level and culture, for example, quizzes and teachers' descriptions.

5.1.2. Design resources and activity sequence based on students' levels and cultures

The content, strategies and activities in LBC should be tailored to students' levels and cultures. For example, students in this study had very poor English proficiency, especially the pronunciation and speaking, so the digital textbook with ample voice facilitation was provided as the resource for the three classes. Besides, a number of games and songs were also utilized to encourage students to open the mouth. Moreover, native culture was introduced as resource to engage students into activities, such as the Bai people's Torch Festival.

5.1.3. Divide work among teachers

As has been mentioned in the previous section, Teacher C undertook too heavy of a workload in this study, so work should be shared among collaborative teachers. This should be considered in the process of LBC design.

Firstly, the lecturer should focus on delivering content, whereas collaborative teachers could try to solve the problems arising from their own classroom. The lecturer's time is reserved only for those unsolved problems. Secondly, collaborative teachers (Teacher A and B in this study) should try their best to coordinate students' activities on their own.

Generally speaking, in the design process, instruction content, strategies, activities should be compatible with students' level and culture. And all participant teachers should play a role in sharing the workload to ensure the feasibility of LBC in the long run.

5.2. Suggestions for implementation of LBC

5.2.1. Suggestions for poor integration of technology into curriculum

It has been made clear that the teachers were not good at using the LBC system which led to a waste of class time. Therefore, technical training for teachers was a must before the implementation of LBC. Besides, teachers should harmonize various elements such as digital textbooks, educational games, and other activities in LBC. Reflection after class is thus of critical importance, because it allows teachers on both sides to share the experience in a timely manner. What's more, curriculum experts could offer suggestions and measures after conducting participant observation.

5.2.2. Suggestions for interaction improvement

Because of the limitation of bandwidth and the large number of students, the interaction among all the students from different sites was not as efficient as expected. Therefore, interaction via the Internet should be reduced only in the sharing stage. Instead, collaborative teachers (Teacher A and B in this study) should help manage their own class interactions in the form of carrying out tasks, repeating or explaining instructions, organizing students to answer questions, and collecting feedback from students in their own classrooms. In this way, it is possible to enhance efficiency of interaction and avoid wasting time.

5.2.3. Specific requirement for the lecturer

To ensure the quality of instruction in LBC, the lecturer should be acquainted with the camera and broadcast system which require her to speak more slowly and clearly than usual, highlight key words and commands if needed, and react properly to instantaneous feedback from all classes.

Besides, the lecturer should pay attention to her teaching manner. To achieve this, appropriate body language should be used, and the utterance and tones must be inclusive for all students.

5.2.4. Establish solidarity among different classes

As has been mentioned, students are unwilling to have a discussion with unfamiliar peers, so it is necessary to establish solidarity among different classes through various measures. The first class, teachers could break the ice through games. Throughout LBC, students in different classes should be grouped together to complete tasks. After class, students from different classes should be encouraged to have more interaction via the Internet. In whole LBC, collaboration rather than competition should be emphasized to reduce stress and to include students.

6. Conclusion

To answer the research question: is it possible to solve educational inequity at the micro level through LBC? The answer is yes to some degree, because in this study, the gap of students' English attitude and scores had been narrowed significantly. However, as mentioned in the literature, different levels of education influence each other. Especially, the economic gap between urban and rural schools resulted in education inequity at the macro level, and it can barely be reduced only through effort in classroom. Moreover, Cheng [11] proposed that family background is also a critical factor for students' education. As we know, the gulf between urban and rural families can hardly be bridged in a short time. In spite of this, the result of this study provides a new perspective for policy makers and administrators.

Moreover, elaborate design is necessary for successful implementation of LBC. Students' levels and cultural background must be paid attention to beforehand whereby proper resources and activities are designed. In implementation of LBC, a number of games and voice and text interactions may be arranged to involve students.

However, there were still some challenges in LBC, such as overwork for the lecturer, lack of classroom facilitation, poor integration of technology into curriculum, and low efficiency in interaction. Some suggestions were therefore proposed to resolve these challenges from the aspects of design and implementation of LBC. Students' level and culture background should be considered prior to designing resources and activities. In the implementation of LBC, the division of labor among different teachers is important to ensure effective interaction and relieve pressure. Moreover, technical training and reflection could help teachers to integrate technology into the curriculum. Finally, the lecturer should deal with the specific challenges from broadcasting, camera angle and students morale in separate class.

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Designing Free-range Assignments

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Abstract. For classes with students from diverse disciplines, professors should consider allowing multiple formats of expression in completing assignments. We call these kind of open-ended assignments "free-range assignments". To design free-range assignments, professors should provide freedom, resources, expectations, examples, reflection, articulation, networks, guidance and evaluation. Professors may also want to consider using technology tools to facilitate the design of such assignments.

Keywords. Free-range, assessment, assignment, innovation, teaching

1. Introduction

Change in technology and educational paradigms are pushing education to be increasingly flexible, authentic, self-directed, and grounded in students' experiences. In such changes, teaching methods are diversifying into hybrid and flipped classroom models. The pace of change in assignments, however, seems slow, with many teachers assessing students using a small number of methods, including quizzes, exams, and written papers. This is an area where we feel significant changes will take place.

Students do not respond alike to the same instruments that are meant to measure their learning. Students having mastered a competency may not be equally capable of demonstrating their mastery with the assessment methods that faculty prescribed. The issue looms large especially for general education courses enrolling students from different disciplines.

What if educators allow students to choose their own methods and medium of assignments, instead of prescribing a specific method and medium that professors deem effective? We found that this is not only possible, but also attractive for a number of reasons, which we will seek to explore in this article.

2. Why Designing Free-range Assignments

We recommend that educators try what we would call free-range assignments, an analogy we take from organic farming. Free-range assignment, simply defined, is the freedom of expression meeting assignment design. With this kind of assignments teachers give students the freedom to choose their own methods of assessment to

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demonstrate competency in a particular area of learning. Faculty have started to do so in various pockets on university campuses, often without naming them free-range assignments, and we thought it probably should be known and adopted more extensively and designed more rigorously for a number of reasons:

Validity and reliability of assignments: For assignments to be valid and reliable, it is desirable to allow for a certain level of flexibility in the way assignments are designed and implemented. For instance, when both English majors and art majors are taking a graphic design course, it is often (not always) possible for English majors to produce better papers while art majors will produce better artistic representations. Mandating one specific kind of assignments risk failing to measure the desired learning outcomes accurately and consistently, and it may put at a disadvantage students who would have produced better work when the medium of expression changes.

Universal design for learning: One of the fundamental concepts in Universal Design for Learning (UDL) addresses disparate needs and unique challenges through a design that is flexible. According to the National Center on Universal Design for Learning (2015), good design provides multiple means of representation (the "what") , multiple means of expression (the "how"), and multiple means of engagement (the "why"). The combination of these three principles call for open-ended assignments types as we propose with the concept of "free-range assignments". The free-range assignment concept may provide students with functional limitations (such as a disability in vision or hearing) the ability to engage in expression without requesting a specific accommodation as required by laws and regulations for students with special needs.

Learner motivation: Free-range assignments allows students to use a medium they are most comfortable with. It also has a motivational factor for students as doing so makes their work more relevant to their fields of study. John Keller's motivation model suggests that for learning to be motivating, it should be relevant (Keller, 2010). Keeping assignments "free range" allows students to select contexts most relevant for them and media they have previously learned to use masterfully.

Competency-based education: A number of institutions, such as University of Wisconsin, has a flexible option to base student assessment on mastery of pre-defined competencies rather than seat time. Using the competency-based models, students have the opportunity to translate experiences into credits. Most universities are not moving as fast due to the lack of understanding about the new model, established organization structures based on seat time, or faculty lack of interest in teaching in alternative models. Yet it is desirable to have some level of competency-based education as many professional licenses and certificates require testing based on competencies. To approximate competency-based education without drastic change in the curriculum and delivery models across the institutions, reform can take place at the course level, where teachers can use free-range assignments to allow students to turn assignments into artifacts that can be used in their real life settings.

3. What is Unique about Free-range Assignments?

Free-range assignments differ from authentic assignments in that free-range assignments encompass certain "traditional" assessment methods, such as papers and exams. Its opposite should be assignments whose format of submission is strictly prescribed by the teachers. We will call the latter prescriptive assignment.

Table 1 describes the differences between the two types of assignments:

Table 1 Free-Range and Prescriptive Assignments

	Free-range assignment	Prescriptive assignment
Competency	same, but could be enriched or enlarged by the variety of assignments	
Instruments	defined by students, examples: ● papers ● blogs ● wikis ● digital stories ● movies ● music ● posters ● concept maps ● expert interviews ● others	defined by teachers, examples: ● quizzes ● papers
Instructions	● vaguely defined ● allows for uncertainty ● includes rubric ● includes examples	● Specific in the format, academic style and even file format
Students' role	● articulate design ● complete development ● explain relevance	● complete assignment in the format described by teachers
Teachers' role	● provide feedback ● provide evaluation rubrics ● facilitate peer review ● grade assignment ● curate past work	● grade assignment ● provide feedback
Designers' role	● guide teachers in finding medium to collect, grade and share coursework ● teach teachers in using technologies	● guide teachers in finding medium to collect and grade assignments.

4. Example Of A Free-Range Assignment

One of the authors of this article, Dr. Jennifer Shewmaker, has had a successful experience with free-range assignments. The idea for the free range assignment emerged from a reading group focused on the book, *How Learning Works: 7 Research-Based Principles for Smart Teaching* (Ambrose, Bridges, DiPietro, Lovett, and Norman, 2010). Shewmaker has taught an upper level undergraduate Child Psychology course for the past eleven years. One of the major assignments within the course has always focused on having each student share their own theoretical understanding of child development. The assignment was completed in three steps, including sharing thoughts at the beginning of the course, then a more refined paper at mid-term, which was a first draft of the final paper and received feedback. Finally, the student completed a final paper in which they addressed the theoretical orientation that their own understanding was most closely aligned with, including areas where they agreed and disagreed. The student then presented their own perspective on several important issues in the field of child development.

Shewmaker's goal with this assignment was to try to provide the students with an opportunity to connect their understanding of child development to a theory in a personal way in order to make it more meaningful. However, after using and refining this assignment, she continued to believe that students were not truly able to understand the theories. Her practice had been to present many different theories and have the student choose one to expand on. The issue seemed to be that they did not understand the theory sufficiently to be able to apply it and expand upon it.

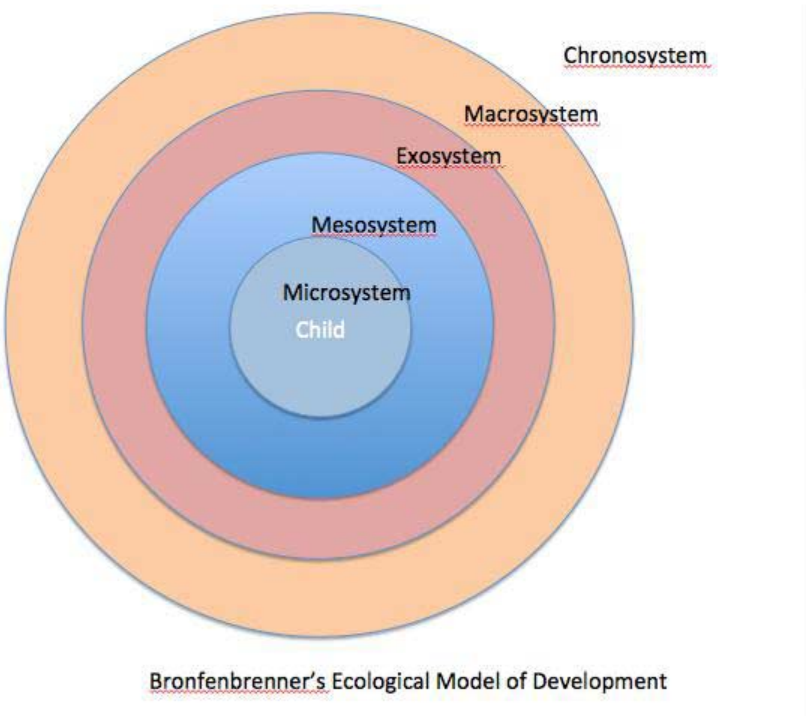

Figure 1. Bronfenbrenner's Ecological Model of Development

As her faculty book group read *How Learning Works*, Shewmaker was struck by the chapter on the factors that motivate students. In particular, on the strategies that the research suggests for increasing the value that students place on course activities. Two of the strategies for establishing the value of the assignment or activity were connecting the material to students' interests and providing authentic, real-world connections. As she pondered her theory assignment, she began to think about how she might aid students in connecting understanding the theory to their interests and making real world connections with the theory.

Shewmaker decided to change the class by focusing on just one theory of development, Bronfenbrenner's Ecological Model of Development (Bronfenbrenner, 1981), and allowing them multiple opportunities to apply that theory to real world situations as well as connecting to their interests by having students consider their own development.

The assignment required the students to define each system within the theory and to consider their own personal development by answering a series of questions about the theory and its application. Taking a constructivist approach, Shewmaker asked students to relate it to their own growth. Students were instructed to share their thoughts "in whatever way you would like", though she did give a few examples, such as paper, digital story, podcast, or film. She found that students produced work that even exceeded her expectations, including a 15-minute video, a digital story, a wind chime, a computer program, and a developmental "clock".

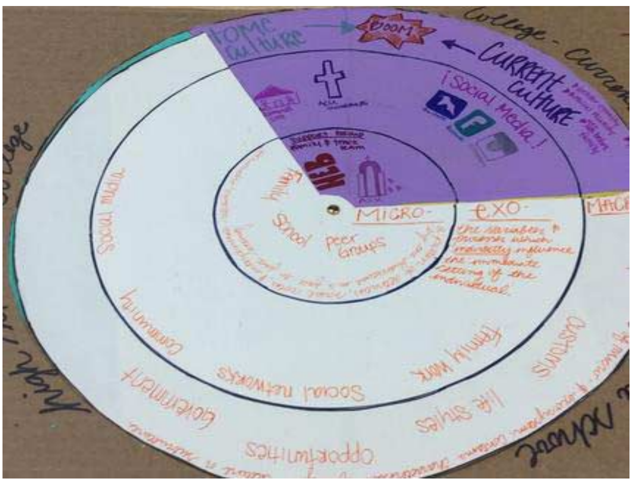

Figure 2. Example of student submission: the development clock

```
import os

def main():
    b = input('\n"There can be no keener revelation of a society\'s soul than the way in which it treats its children." \n -
Nelson Mandela \n\n Press enter to continue')
    b = input('\nToday, the life of a young child is in your hands. \n In some sense, this is no different from real life. You
may not be their parent, but all parts of a child\'s surroundings affect the person they become.\n\nPress enter to continue.')
    b = input('\nIn this simulation, you will take the role of various systems of a child\'s life that will influence
development. You will make some difficult choices that have consequences. \n\nPress enter to continue')
    b = input('\nThe bioecelogical model anticipates the way a person and an environment will interact. You need a person, so
let\'s get started. \n\nPress enter when you are ready to begin the simulation.')
    os.system('clear')
    b = input('\nThroughout this simulation, you can always press enter to continue. When entering a choice, you will type one
letter and then press enter. Because I am a bad programmer, failure to make a choice or enter it correctly may cause a crash and
force you to reset the program. \n\nCAUTION: Please remember when you select decisions to only type in lowercase letters!')
    os.system('clear')
    b = input('\nApril 7th, 1991: It\'s a boy! His parents have named him Levi. Based on his genes, he will grow brown hair.
\n\nChoose an aspect of his temperament by typing the corresponding letter and pressing "enter": \n\n a. Flexible\nb. Active\nc.
Cautious\n')
    os.system('clear')
    b = input('\nJust kidding! Temperament is a force characteristic. You cannot control this, nor can Levi, strictly speaking.
He has a cautious temperament type. \n\nPress enter to continue')
    b = input('\nThe bioecelogical model divides a child into force, demand, and resource characteristics. Force characteristics
are those such as motivation and temperament. \n\nDemand characteristics are things that serve as a stimulus to those in the
environment, such as race and appearance.\n\nResource characteristics are the resources the child brings to the table, including
cognitive, emotional, physical, and material resources. \n\nPress enter to continue')
    os.system('clear')
    b = input('\nWe already know about a few a Levi\'s demand, characteristics, as well. He is a caucasian male with brown hair,
for example.')
    os.system('clear')
    parenting = input('\nTime to make your first real choice. Which of these resources will become available to Levi? \n\na. A
safe, comfortable home environment. \nb. Above average early skills for written language\nc. Gradually increasing creative
skills')
    b = input('\nYou chose that one? Okay, I guess you\'re the boss...\n\nPress enter to continue')
    b = input('\nNot even two years have passed and there\'s already another kid taking the spotlight away from Levi. 1.6 years
later, Levi\'s sister, Rachel, is born. \n\nPress enter to continue.')
    b = input('\nLike Levi\'s parents, Rachel is part of the microsystem, the system consisting of things that interact directly
with the child. Research shows that siblings are at least as influential as parents, if not moreso. \n\nPress enter to
continue')
    micro1 = input('Which of these traits will Rachel have that influence Levi?\n\na. A passion for dance\nb. A tendancy to lie
to avoid punishment\nc. A love for animals\n\nType the lettere corresponding to your answer and press enter.\n')
    os.system('clear')
    b = input('\nInteresting... \n\nPress enter to continue')
    micro2 = input('Now age 4, Levi\'s extrafamilial influences are beginning to have a greater influence on his development.
Which of these will be true of his social environment?\n\na. He will be homeschooled\nb. He will be heavily involved at
church\nc. He will play organized sports with other kids\n')
    os.system('clear')
    if parenting == 'a' and micro2 == 'a':
        b = input('\nHomeschooling? Fitting, considering his safe and comfortable home life. I wonder how it will affect his
social competencies, however.\n\nPress enter to continue')
    if parenting == 'b' and micro2 == 'a':
        b = input('\nHomeschooling? Hopefully that fosters his natural language skills. One wonders how it will affect his
social competencies, however.\n\nPress enter to continue')
    if micro2 == 'b':
        b = input('\nChurch will be his primary source of social interaction with peers. Here\'s hoping church produces good
apples and not rotten ones, or that your choices make Levi resilient enough to withstand the bad.\n\nPress enter to continue')
    if micro2 == 'c':
        b = input('\nHe has no natural talent for them, but perhaps the friends Levi makes in soccer will be worth it.\n\nPress
enter to continue')
    b = input('\nYou have made some important decisions so far, so you will now engage Levi\'s development from the perspective
of the "Chronosystem", or the interaction of person, process, context, and time. \n\nPress enter to continue')
    b = input('\nSo far, you have made decisions about the person and the context. How will these processes interact over time
based on the decisions you\'ve made? \n\nPress enter to continue')
    firstresult = ''
```

Figure 3. Example of student submission: computer program

Overall, Shewmaker's students' were better able to demonstrate mastery of their knowledge compared to previous paper assignments. Student understanding of the theory as measured by the grade rubric indicated a higher percentage of students demonstrated a deeper level of understanding of the theory. Shewmaker believes that there were two components that led to this change. Firstly, she changed the approach to teaching the theory, and instead of trying to provide a shallow skimming of many theories, created an opportunity for deep learning and application of one particular theory. Secondly, she provided students with an opportunity to choose their mode of expressing their knowledge of the theory and its application.

Shewmaker asked students for feedback on the assignment. Many had never had an assignment in an upper level course that allowed a choice in expressing their knowledge. They said that they enjoyed the option, but were a bit wary about knowing what would and would not be considered a successful project. Many said that this type of assignments would be appreciated best by self-directed learners. The challenges associated with this type of assignment were trying to "think of something creative to do, since writing a paper is the norm for this sort of final project." Students also noted that the open nature of the assignment made it tempting to procrastinate, since a creative project might take more or less time depending on what they decided to do. Several suggested that they were not prepared for the amount of time it would take to complete the assignment due to the fluid nature of the assignment. For example, several students had planned to create a video project, but realized in the midst of preparing it that the assignment would take substantially more time than they had allowed. This led them to revise their plan.

Advantages noted were the ability to choose something that was personally interesting to the student, which "gave me the motivation to work harder and longer than I would on a paper or ordinary project."

5. Suggestions for Designing Free-Range Assignments

Free-range assignments are not necessarily easier assignments. Due to the lack of a fixed model of expression and process, they are often more complex for students to grasp at the beginning. With the complexity come ambiguity and uncertainty, which often leads to anxiety and frustration, especially for those used to guided and structured learning. It is not easy assignment for teachers as well, as it is a tough challenge to grade diverse types of assignments without sacrificing the rigor of assessment. Here are a few suggestions to increase the chance of success in the design of free-range assignments. For the ease of memory, we use the acronym "FREE RANGE" as a structure for making our suggestions.

Freedom: The defining characteristic of free-range assignments is the freedom professors give to students. Such freedom is as liberating as it is terrifying. With freedom comes the need for exploration and experimentation. Failure is not unknown in these territories. Professors have to be prepared to accept more types of artifacts than they might be used to. Use the freedom to empower students to think creatively about ways to demonstrate their learning. The freedom could also mean that some students will default to their preferred traditional methods for assignments, for instance, writing papers. Make sure that is encouraged as well. The point is to liberate students to use tools they are best at to demonstrate their learning. It is not meant to punish students to use methods that do not seem to be "creative". For those choosing to experiment with some emerging technologies or methods, the freedom in free-range assignments should also give students the responsibility to learn additional tools to develop their assignments work if they choose to use a medium and method they are not yet comfortable with.

Resources: The success of free range assignments depends on student creativity as well as resources teachers can guide students to. Provide or guide students to rich resources, including media production assistance and facilities that the university may provide, as well as tools they can use to produce their products. If students produce a digital story, professors might want to let them know where to learn to use the tool. Professors can invite university media specialist to come to their classes for a guest lecture, or direct students to watch videos from sites such as Lynda.com, which can teach them to use various digital tools, such as iMovie or Camtasia.

Expectations: Not all students will like the idea of allowing them to choose their own assignments. There might be some anxiety, especially for those "good" students who have become comfortable with more "traditional" types of assignments. Professors may want to explain the learning outcomes they are looking for, and tell students that they may experience some confusion and anxiety in the project, but that with persistence and grit, they will be able to overcome that.

Examples: Free-range assignments get easier to manage over time. Teachers will need to assemble a repository of examples that can be shown, with permission from their owners, to future classes. When students are totally clueless about the kind of assignments they can produce, showing examples from previous classes or other universities will inspire them to think of their own.

Reflection: Free-range assignments can have an especially powerful impact upon learning when students are able to reflect on the assignment as part of the evaluation process. Consider asking them to evaluate their own work by asking questions that prompt them to imagine what resources would be necessary to improve the products. Students may have discovered late in the project that other related concepts could have been incorporated. These reflections are valuable to students, as they lend permanence to the concepts they have explored in the project. Student reflection also provides excellent feedback to the instructor to assist students in subsequent classes.

Articulation: Shifted from prescribed learning situations to self-defined contexts, things can get messy, at least at the beginning. But as such mess can be embraced (Block, 2015). Similarly, the book *A Perfect Mess* argues for the hidden benefits of "mess", such as the potential to enhance creativity (Abrahamson & Freedman, 2008). However, mess can be productive only if professors can work with students to develop articulation in the process. Set up proposal stages in the assignments with students. Help them to articulate what they want to accomplish using a process for them to propose, outline, draft and revise their assignments. Make the process incremental and iterative so that it is possible for them to develop clarity throughout the process. It is also key to develop a rubric to define what excellence in assignment looks like, components they should include, and the rating scale professors will be using. This rubric itself is an educational tool to reinforce their understanding of the learning outcomes as well as quality standards professors will be using.

Networks: Harness the power of networks for free-range assignments. Group work can be an option for such assignment, especially when large, complex work is required. Even with individual work, professors can encourage students doing similar work to form groups to learn similar tasks together. For instance, students producing movies may be encouraged to form peer groups to learn production techniques together. In addition, before student present their work to professors, professors might have a step for them to review each other's work. That might help them to improve on what they have done. It may also create some healthy peer pressure for better learning results. Networks should not be limited to the boundaries of the classrooms. Students can consider networks with other people in the field.

Guidance: Breaking down a large authentic project into smaller ones. For instance, have a process to guide them through such steps as the initiation of project idea, gathering or resources, development of a storyline, and the development of final product. Professors should do so for papers as well as movies. For papers, ask them to present the professor a topic, and then an outline and bibliography, and then a draft, and in the end a final draft. For movies, professors might want to ask for their proposal, then a storyline, then see a short segment of their produced material and towards the end professors expect them to show a final project. In each of these steps, provide feedback to keep students on the right track. Professors could also schedule one-on-one meeting with students to discuss their project ideas. It is important to make some of the early steps low-stake, allowing students to fail early and explore more broadly, while assigning greater weight to the final product.

Evaluation: Free-range assignments, if used initially, will be prone to pitfalls on many fronts, from the management of student anxiety to technical issues. Be open to evaluate professors' own practices. Think what professors would do differently next time. Use end-of-semester course evaluation as an opportunity to gather student feedback on what works and what does not. Professors might also want to conduct a mid-semester evaluation to gather feedback so that professors can make adjust their instructions or methods accordingly for the benefits of the present class. Use evaluation from one class to help another class. For instance, at the beginning of the semester, it may help to ask students from an earlier class to reflect or give suggestions about assignments to the next class.

6. Utilizing Technology for Scaffolding

As described above, free-range assignments require much clarification and guidance. Technology can provide great scaffolding for the completion of such assignments. Here are a few examples of what technology can do to provide scaffolding for the design and implementation of such feedback.

Individualization: Technology can come to great assistance when it comes to individualizing teaching content and activities. With most mature learning management systems it is possible to set up individualized release of content based on completion of prerequisite tasks. For free-range assignments, professors may want students to develop an initial knowledge base before they proceed to their projects. Using some initial generic assessment tools such as quizzes or reading responses, professors can allow students to work at their own pace to build the initial knowledge, skills or attitudes which will be important to the success of their individual assignments. During the project, it is also possible to allow students to work on their paces as students' design, development and implementation timelines may not be the same for the projects of their own choice.

Community: Technology can help to shape a community among students so that they figure out what professors want together. This way students struggling with an assignment can share ideas or frustration with each other. Simply having some open discussions for the class may help form such community.

Collection: Professors can use assignment tools to collect student artifacts (including photos or videos or artifacts that cannot be uploaded online) and share them, using tools such as Google Drive and Shared Evernote folder.

Grading: One of the biggest complaints I hear from faculty using similar assignments is that it is very difficult to grade diverse assignments. If a professor set up rubric online, it should make the task much simpler. Learning management systems like Canvas allows professors to grade with rubric.

Feedback: Technology can also help send feedback to students. By using tools such as Voicethreads, professors can provide rich audio or even video feedback to students. Some learning management systems now also offer the option to provide feedback in a variety of format, including text, audio and video.

7. Conclusion

In higher education, arguments about educational assignments sometimes are binary, with people subscribing either to positivist traditions or constructivist traditions of assignments. With the former, professors control the forms of assignments they deem effective for understanding the achievements in learning. With the latter, professors allow students to bring in their prior knowledge, backgrounds, and contexts in their assignments. There are times when a simple either-or choice does not work best to get the full picture of students' learning. We coined the term free-range assignments to encourage faculty to explore more holistic assignments options which allow for "all of the above" choices. By giving students choices, and using technology to support their assignment completion effort, we hope it is more effective to cause learning to happen.

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A Social Knowledge Network-Based Intelligent Framework for Finding Right Persons in OKCs

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Abstract. With the rapid expanding of learning content resources and users, it is difficult for learners to find right persons they need as knowledge experts and learning peers in open knowledge communities (OKCs) using traditional search engines. According to this situation, the paper presents a social knowledge network-based intelligent framework for finding right persons in OKCs. The architectural details of the framework are proposed in this paper. The authors expound the idea of the intelligent framework design, the work principle and mechanism of each module.

Keywords. right persons finding, SKN, ontology, linked data, SWRL, LDA, SNA, Learning Cell Knowledge Community

1. Introduction

Open knowledge communities (OKCs) are online and open learning environments which provide good opportunities for taking part in knowledge authoring and sharing collaboratively and exchanging knowledge, experience and resources among users [1]. Better person-to-person interaction, discussion and collaboration in OKCs may not only solve learning problem immediately to improve learning performance [2, 3, 4, 5], but also eliminate the study of loneliness effectively to improve learning satisfaction and motivation [6, 7]. However, with the rapid expanding of learning content resources and users in OKCs, it is difficult for learners to find right persons they need as knowledge experts and learning peers using traditional search engines.

Proving right persons finding service for learners to search right knowledge experts and learning peers efficiently is vital for smart learning, because right persons may offer authoritative, trustworthy knowledge and collective intelligence for learning. Based on the idea, the paper presents an intelligent framework for finding right persons

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in OKCs employing hybrid technologies. The architectural details of the framework are designed in this paper. Authors also expound the idea of the intelligent framework design, the work principle and mechanism of each module.

The rest of this paper is organized as follows. In Section 2 are presented related works. Section 3 presents our statement of the problem. Section 4 describes an intelligent framework for finding right persons employing hybrid technologies. Finally, Section 5 presents our conclusions and future work.

2. Related Works

The experts finding is also called expert search or expert location that is aimed at discovering the relevant experts with higher authority knowledge. TREC set up experts finding task in 2005. There are many studies on experts finding to find persons with higher expertise, experiences, or skills in organizations and open online communities.

The earliest experts finding systems for organizations focused on expertise identification based on description information of experts' skills stored in a structure database [8, 9]. With the rapid expanding of information in the internet, experts finding for open online communities have been attracted more studies [10].

Many approaches and algorithms are proposed to finding experts. The language model is used to calculate probability between query topics and candidate experts [11, 12, 13]. Topic-sensitive probabilistic model is proposed to find expert in question answer communities[14].Through the construction of the users' social network, methods based on social link network analysis have achieved experts finding in open communities (such as Yahoo! Answers or Java forums) and enterprise organization [15]. Ontology can provide formal and sharable representation of knowledge. Based ontologies experts finding method is also proposed to improve the search results [16, 17, 18, 19]. At the same time, there are many hybrid methods proposed to find expert using language model, topic model and social network linked analysis [20, 21, 22].

Previous studies provide approaches for the right persons finding in OKCs. However, these studies mainly focus on finding persons from the view of knowledge while ignore different learning needs and persons' roles in OKCs.

3. Problem Statement

In the OKCs environment, users and knowledge are linked through various social learning interactions among users and knowledge. In the process of social learning interactions, a user in OKCs has different roles such as expert, peer, learner, and so on. For example, when a user has created a lot of knowledge relevant to Java Programming, it seems most likely that the user is an expert in the field of Java Programming. As learners, they have different learning needs in different context. Sometimes, learners hope to find the authoritative knowledge experts relevant to specific topics to solve problems in learning process. Sometimes, learners hope to find peers who have the same interest for discussion and communication. Therefore, as for learners, experts and peers are the right persons for learning. So, based on the above two contexts, we defined our research problem that is how to find the right experts and peers for each learner efficiently and effectively in OKCs. Figure 1 depicts research question.

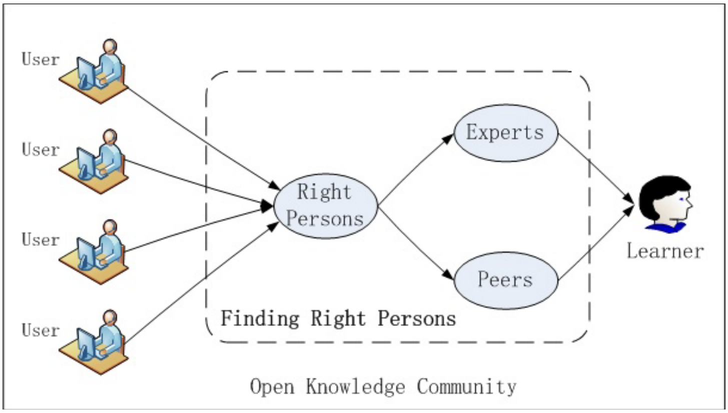

Figure 1. Research statement of finding right persons

4. RPFinder : An Intelligent Finding Framework

The intelligent right persons finding framework called RPFinder includes seven components logically: SKN Construction, RPs Generator, Query Semantic Parser, Semantic Matching, Semantic Reasoner, RPs Ranker and RPs Finding GUI. The architecture of RPFinder is illustrated in Figure 2.

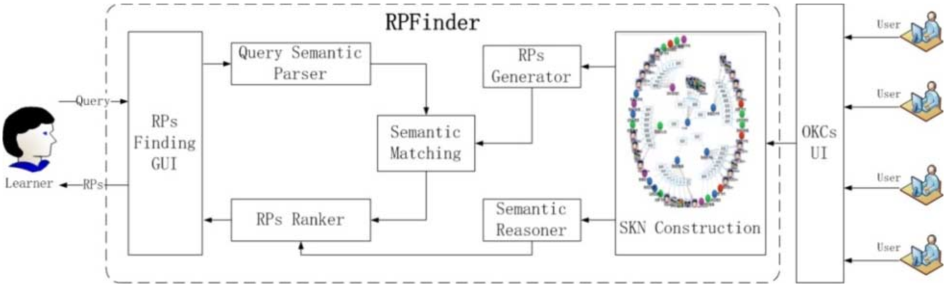

Figure 2. RPFinder intelligent finding framework

4.1. SKN Construction

In OKCs, people and knowledge are connected with each other through various social learning interactions in different learning contexts. Due to various learning interactions between people and knowledge, OKC forms a social knowledge network (SKN). SKN is a composite representation of graph model of a social network and knowledge network, specifically with RDF semantic graphical representation. The aim of SKN Construction is to build a semantic linked data network. We define the social knowledge network as follows:

Definition (Social Knowledge Network). SKN = <N, R, L> where

- N = <PN, KN> represents the collection of nodes, where PN represents a collection of person nodes, KN represents a collection of knowledge nodes;
- R = < P2P, P2K, K2K > represents the collection of relations, where the P2P is a collection of relations among persons, P2K represents a collection of relation

between persons and knowledge, K2K represents a collection of the relationship between knowledge and knowledge;

- L:R → N represents correlation function, the associated relationships with person and knowledge nodes.

Ontology is a semantic organization technology for explicit and formal description about concepts, properties and relationships providing high level meaning. Ontologies are important for the SKN Construction. We use two ways to build the ontologies. One way is to construct an ontology called SKNO for explicitly and formally describing person, knowledge and their social interactive relations in OKCs from the learning perspective. A part of class hierarchy of the SKNO is illustrated in Figure 3. SKNO consists of three type classes: *Knowledge, Person and PKR*. *Knowledge* is an abstract concept including different learning resources such as a learning object, a learning tool, a learning cell and so on. *Person* is a concept to represent actor involved in learning process which consists of three sub-concepts: *Learner*, *Peer* and *Expert*. *PKR* is composed of three type classes *P2P*, *P2K* and *K2K* representing different relationships between *Person* and *Knowledge*.

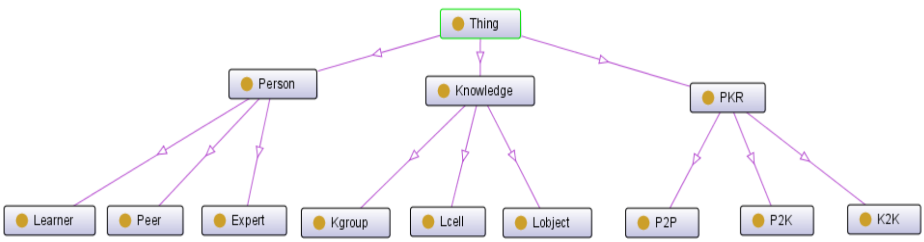

Figure 3. A Protégé screenshot representing a part of class hierarchy of the SKNO

Another way is to utilize and extend the existed ontologies such as LOM for describing the learning content, DC for general web resources description, SKOS for relevant concepts and taxonomy description, FOAF for people description, and so on.

Linked data facilitates web-scale data interlinking and realization of semantic knowledge network based on a set of well-established principles and W3C standard technologies, e.g. RDF, SPARQL, HTTP URIs [23].

SKN Construction is aimed at generating social knowledge network employing the above ontologies and linked data technologies to link person and knowledge from the OKCs log. SKN is a RDF graph for storing semantic and linked learning data. Figure 4 depicts an example of SKN.

4.2. RPs Generator

The represent of Right Persons (RPs) is the core function of the RPs Generator. In OKCs, person as an entity has many characteristics in the view of learning offer. From the perspective of knowledge, RPs should have the higher degree of correlation in the specific domain knowledge. From the perspective of knowledge quality, RPs should have the higher degree of knowledge authority. Meanwhile, the availability and reputation of the RPs are the important factors for learners.

Taking into consideration of the above characteristics of the RPs, we define five parameters to represent RPs including knowledge-related degree (KRD), knowledge-authority degree (KAD), social reputation degree (SRD), community availability degree (CAD) and community usability degree (CUD). According to five parameters model of RPs representation, five two-dimensional matrixes (KRD matrix, KAD matrix, SRD matrix, CAD matrix and CUD matrix) are created to represent RPs and relationships between RPs and knowledge.

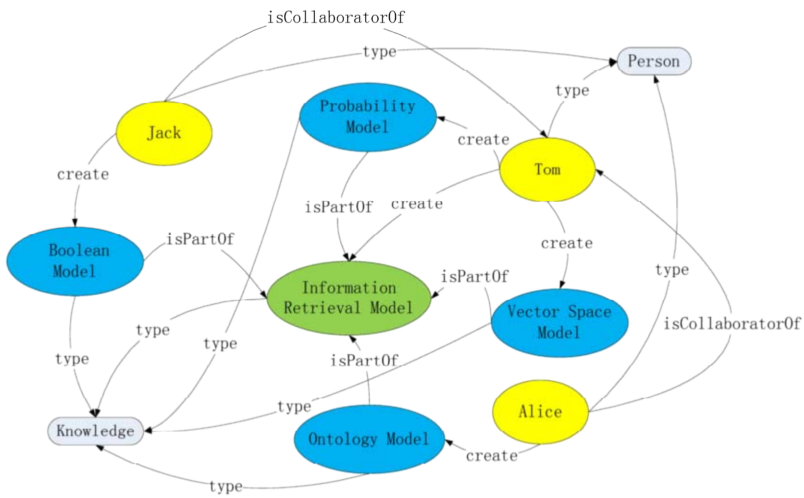

Figure 4. An example of SKN

RPs Generator can generate the five two-dimensional matrixes employing hybrid technologies base on SKN. For the matrix of KRD, we use expert finding approach base on topic mode (LDA) [14] to compute the relevance between RPs and knowledge. For the matrix of SRD, we use social network analysis techniques (SNA) to compute the social reputation of RPs. For the matrix of KAD, semantic link analysis techniques are utilized to compute knowledge-authority of RPs. For the CAD matrix and CUD matrix, we use SPARQL to get data from SKN.

4.3. Query Semantic Parser

Semantic Parsing is the process of converting query into a formal and logical meaning representation to understand learners' real learning needs. Query Semantic Parser is designed to get semantic information from the learners' request employing the general ontologies and domain ontologies that is aimed at enriching search query information.

4.4. Semantic Matching

Semantic Matching is aimed at computing semantic relevance between the output of Query Semantic Parser and the characteristics of RPs generated by RPs Generator. The LDA mode is utilized in the process of the semantic similarity measures of Semantic Matching.

4.5. Semantic Reasoner

Semantic Web Rule Language (SWRL) is an expressive rule language that enables users to write rules that can be expressed in terms of OWL concepts to provide powerful logical reasoning capabilities [24]. Semantic Reasoner is designed to finding new relationships in SKN. A SWRL rule defining is as follows: isCollaboratorOf(?x, ?y) ^ isCollaboratorOf(?z, ?y)-> Peer(?x, ?z). In this rule, isCollaboratorOf(?x, ?y) represents that ?x is collaborator of ?y and Peer(?x, ?z) represents that ?x is peer of ?z. If the relationship between isCollaboratorOf(?x, ?y) and isCollaboratorOf(?z, ?y) is satisfied ,then Semantic Reasoner can get new relationship Peer(?x, ?z) . Using the above rule, Semantic Reasoner can get latent semantic relationship in SKN and find new relations among persons to get more social network information in SKN.

4.6. RPs Ranker

After the process of Semantic Matching and Semantic Reasoner, the RPs Ranker gets the calculation result to rank the RPs according to the five parameters model of RPs representation, so as to evaluate the RPs from five perspectives..

4.7. RPs Finding GUI

RPs Finding GUI is a graphic user interface for accepting learners' query and providing multi-visual right persons finding results. RPs Finding GUI provides two types of finding service: Peers Finding and Experts Finding. Learner can choose the finding service. As for learners' query, it provides friendly search textbox to enable learner input query request in the format of keywords or natural languages. It also offer quick search templates and advanced search functions for learners to satisfy learners' different needs. After inputting, RPs Finding GUI provides finding knowledge relevant persons with different views: list view and network view.

5. Conclusions

Finding right persons is vital for smart learning. If we find right persons, we can get the channels to gain knowledge and communication opportunities. This paper introduces the design of an intelligent framework for finding right persons in OKCs. Considering the social interaction characteristic of OKCs, a novel SKN model is proposed to represent the integration space of social network and knowledge network utilizing the ontologies and linked data technologies. Based on the SKN construction, functions and mechanism of the modules of RPs Generator, Query Semantic Parser, Semantic Matching, Semantic Reasoner, RPs Ranker and RPs Finding GUI are designed and expounded.

For the future, we will develop and realize the intelligent right persons finding system (IRPFS) in our Learning Cell Knowledge Community (http://lcell.bnu.edu.cn/) which is an online and open knowledge community to provide intelligent finding service for learners. The IRPFS will be implemented based on many open-source ontology editors and development tools such as Protégé, Jena, SWRLTab, Jena TDB and so on. We will test and evaluate the RPFinder in different learning context using qualitative and quantitative methods

Acknowledgments

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CALCULENG : Towards an Intelligent Environment for the Teaching and Learning of Calculus

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Abstract. Development of proficiency in mathematics is an essential aspect of many higher education programmes of study. This applies both to specialist mathematics students, and students of many other disciplines, including engineering, most natural sciences and some social/human sciences, business and commercial subjects. Students' knowledge of and expertise in mathematics (or lack thereof), at least at an elementary level, can have a major impact on many other areas of their studies and their subsequent career prospects. However, mathematics is an area which many students find difficult, particularly those from "non-traditional" academic backgrounds, including disabled and mature students, and they often do not realise its relevance and importance to their other courses, nor do they (or can they) devote as much time or effort as they perhaps ideally should, and face to face tutorial support is often limited. In this paper, we describe the design, development and initial evaluation of CalculEng, a system to offer such tutorial support for learning differential and integral calculus - primarily aimed at Engineering students. This system provides structured questions, which are automatically marked, with the aid of a Computer Algebra System, and intelligent, relevant feedback - based on the mistakes made by the student - provided. At present, this feedback is hard-coded using expert-entered rules. However, ways in which the system could be made to intelligently learn patterns of common student errors, and offer feedback accordingly, are being investigated. Our resources should be of particular benefit to students who, due to disabilities or family commitments, may have difficultly attending classes in person.

Keywords. Computer-Aided Teaching & Learning, Calculus, E-Learning, Automated Tutorial Support, Automated Assessment, Intelligent Feedback

1. Introduction

Mathematical skills are core aspects of most scientific, technical, business and finance degrees. Proficiency in mathematics – at least at an intermediate level – is essential to any professional engineer or scientist. However, these mathematical topics are often found difficult by students, particularly those from "non-traditional" academic backgrounds, including disabled and mature students, who may have problems attending classes due to mobility, working or family commitments, and in accessing traditional support resources [9]. Furthermore, the class time available for face-to-face

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tutorial support for mathematics in other disciplines is often limited, and class sizes – even for tutorials – are frequently rather large compared with the number of tutorial support staff available. These factors pose major challenges for both students and academic staff.

There have been many attempts to address such issues. Since the 1960s and 70s, academics teaching mathematics to engineering students investigated the potential of using "Programmed Learning" approaches in course materials and textbooks. In this methodology, theoretical concepts were introduced in conjunction with a large number of worked examples, broken down into small individual "steps" or "tasks" and arranged in a way such that students could "cover up" the latter parts of the model answer, try each task themselves, then reveal the next part of the model solution and compare that with their attempt. This approach led to several highly successful textbooks, including the very popular volumes by Ken Stroud [18] – Stroud's "Engineering Mathematics" is now in its 7th edition [19] and as popular as ever with students.

Some higher educational establishments have gone for an approach which restores the more traditional face-to-face approach to tutorial support, but in a more flexible way. An example of this is the system of "MathsAid" drop-in clinics held at Kingston University and some of its affiliated colleges [1]. At each campus, drop-in sessions are held most weekdays (usually for 2 or 3 hours around lunchtimes) run by either a member of academic staff, postgraduate student or senior, trained undergraduate student. These sessions are designed to provide support to students of all disciplines who are having difficulties with mathematical and/or statistical concepts and exercises which they encounter during their studies, no matter what their main area of study is. Hence, in addition to people taking mathematics or statistics as their principal subjects, many students from chemistry, biology, economics, business, or engineering subjects attend these sessions in order to resolve issues and problems. However, it is always emphasized that these sessions are not there to give students answers to assessed exercises [1]. Moreover, these sessions are not substitutes for their regular tutorial sessions on their courses.

More recently, some computer-based and on-line resources and exercises have been developed to address these issues for teaching and learning mathematics. A few example of these are the CATAM [7], CALMAT [2, 5, 11], Mathletics [6], MathDox [3], GeoGebra [8] and STACK [15, 16], and there are also commercial systems such as MapleT.A. [14] and MyMathLab [13]. Each of these systems has some good and some poor aspects, and only a few of them, such as STACK, provide any feedback on the students' answers. CALMAT is primarily targeted at senior high school students and the core material it covers is more at a rather elementary level. Additionally, it only permits multiple choice and short answer questions and, although these questions may include an option to reveal a "hint" to students in the middle of an attempt at solving them, the restricted type of responses which may be entered do not permit checking of a student's answer for algebraic consistency with the model solution, nor do they offer meaningful feedback to students. Similarly, the "Mathletics" system developed at Brunel University in London [6] only offers a limited range of question types and only very basic feedback to students on their answers, which is not tailored to the specific nature of the student's mistakes. Furthermore, MapleTA [14] and MyMathLab [13] are proprietary systems, with subscription payable. Although the MathDox system developed at the Technical University of Eindhoven [3] covers a more comprehensive and advanced range of mathematical topics, and is interfaced with a Computer Algebra

System (CAS) which enables the checking of students answers and working for consistency, most of the resources developed for it are currently only available in Dutch !

In many institutions, a Virtual Learning Environment (VLE), such as BlackBoard or Moodle, is used as a tool for formative and/or summative assessment. The method of assessment normally uses very short answer or multiple–choice questions (MCQs) that are not well suited for the assessment of mathematical topics. Additionally, this form of assessment tool fails to provide a useful and detailed feedback.

However, appropriate on-line resources and exercises should provide additional "virtual tutorial" support at any time and location, which is consistent with the expectations of modern students. Hence, the use of suitable e-materials is expected to improve the quality of student's learning as these materials would provide a platform which will allow students instant access at anytime and anywhere. Furthermore, use of structured exercises will allow the students to develop and test their own knowledge and understanding of mathematical topics, concepts & methods. Linking the system to a Computer Algebra System (CAS) will also enable checking of the student's answers for mathematical/algebraic *consistency* with, rather than requiring an exact match to, the model answer, allowing answers to be expressed in different, but equivalent and possibly equally correct, forms and still being marked as "correct". Furthermore, use of this CAS, in conjunction with hand-crafted rules encoded in XML, allow the detection of "common errors" in solutions, and the possibility of offering constructive feedback specifically tailored to the error(s) the student has made.

Identifying all the above issues has helped us to create an on-line system, called CalculEng, covering a good range of intermediate level calculus topics, allowing students to carry out a series of exercises, and offering hints and meaningful feedback, dependent on the student's answers. These resources not only have the benefits of both computer-based and face-to-face tutorial support but also, by breaking exercises into small stages, in the spirit of "programmed learning" textbooks, they should assist students to learn and master the essentials of differential and integral calculus.

The aim of this project is firstly to evaluate these on-line materials by using both qualitative (e.g. via questionnaires) and quantitative (via students' performance in formative assessments) perspectives, and then to investigate ways in which the system could become more intelligent, by observing and analysing students' answers – including their errors and mistakes – and learn from these, adjusting the feedback offered to students in a way tailored to the individual student's responses, ideally without having to rely on hard-coded rules devised and entered by an expert.

2. Development of CalculEng and Resources for its Use as a Virtual Tutorial Tool

The initial development of CalculEng was inspired by the existing QTIworks system [21] hosted at the University of Edinburgh, U.K. This system allows tutors to author tutorial-style mathematical exercises, encoded using a variant of XML, and have these rendered on-screen, employing MathML to represent mathematical equations and formulae, with the aid of a MathML-LaTeX conversion tool called SnuggleTeX [4]. QTIworks exercises can be linked to the freely-available Maxima [17] Computer Algebra System, allowing student's answers to be checked for mathematical consistency with the correct solution, and hence permitting far more flexibility than just multiple choice or short answer questions which require an exact match to the model solution for the student's response to be considered correct. The QTIworks project encourages tutors to submit their own resources and questions to be hosted on their site. However, at the time of writing, only materials on relatively elementary mathematical topics were available to the public via QTIworks. Notably, those QTIworks resources in existence for the teaching and learning of differential and integral calculus, which are essential aspects of many university courses in science, engineering, economics and other disciplines, were at a rather trivial level, more appropriate to senior high school, rather than University, mathematical studies. This prompted the need to develop new resources, suitable for the teaching and learning of calculus at a sufficiently advanced level to meet the requirements of at least the first year university curriculum.

We decided that the QTI framework was suitable for our needs and, although requiring a large amount of effort per question, a user-orientated tool [12] was available for facilitating the mark-up of questions and their solutions in the QTI variant of XML. We also identified that offering students feedback on their solutions – whether these were correct or incorrect – would be invaluable, and that, provided the nature of the errors they had made in an incorrect attempt at a question could be determined, this feedback could be tailored to the mistake(s) the student had made. Furthermore, if a set of "common, standard errors" were determined for each question and marked-up in QTI XML, the student's response could be checked against this using Maxima and feedback appropriate to that particular error could be given to the student. This set of features should make our QTI-based system a very useful "virtual tutorial" support tool for students learning calculus – and potentially also to their tutors. We decided to call our system "CalculEng", which could either be considered to represent "Calculus Engine" or, since the system was initially intended to support Engineering students learning calculus, "Calculus for Engineers".

In an attempt to follow the "programmed learning" approach adopted by successful textbooks such as Stroud's "Engineering Mathematics" [18, 19], CalculEng offers students structured exercises on elementary differential and integral calculus (including applications of both of these), such that the students can enter their answer to each section as a mathematical expression, typed-in using an ASCII-based mathematical format (an example of this is shown in Figure 1 below), rather than just making a selection, as is the case for multiple-choice questions, or just entering a numerical value. Although the general nature and structure of each question is pre-defined, specific parameters and coefficients in formulae and equations can be selected randomly (within limits or ranges pre-specified by the tutor, e.g. in order to ensure that a quadratic equation involved in the solution has real roots) automatically by the system. The system then checks the student's response for algebraic consistency with the "model answer", using the Maxima computer algebra system [17] and whether the format of the response is correct (e.g. has the student simplified his/her answer sufficiently ?). Furthermore, a set of rules, encoded in XML, for each question, allow the student's answer to be checked against a list of perceived "common errors" for that type of problem (e.g. has the student differentiated a function which the question required him/her to integrate ?), and then provide feedback tailored to the particular type of mistake made. This is expected to assist students with understanding and mastering mathematical concepts, and ultimately should help them in problem-solving situations in their main subject of study. In multi-section questions, detailed feedback will be revealed to the student in a step-by-step process. This feedback facility, customised to the precise question and student answer, is a particularly powerful feature of CalculEng, as it can be used for both formative and summative assessment.

Expression as rendered on-screen : $7e^{(3z-2)}\cos(5z-6)$

ASCII Format : 7*e^(3*z-2)*cos(5*z-6) or 7e^(3z-2)*cos(5z-6)

Figure 1. ASCII-based mathematical format for a student entering a given mathematical expression.

The calculus exercises used in CalculEng were originally selected from conventional paper-based tutorial exercises which two of us (MD & GH) had developed over many years of teaching calculus at foundation and first year university level. However, some further, primarily engineering application-based, exercises were put forward by another of us (JD), who is currently completing his MEng degree in Engineering at Kingston University. Model solutions were prepared by the person who had originally set each question, and some anticipated "common student mistakes" (e.g. the student forgot to include the correct multiplying factor in a differentiation exercise using the "chain rule") identified for each one. Appropriate constructive feedback comments were devised for each anticipated answer – correct, consistent but not simplified, any particular "common mistake" or "otherwise incorrect" – and the question and each of the expected attempts at solutions encoded using QTI XML code [12].

An example integration exercise is illustrated in Figures 2 – 6. Firstly, the question, and a student's answer containing an anticipated "common mistake" are shown, as rendered on the screen, together with the system's feedback for that particular "common mistake" (Figure 2). This is followed by excerpts of the XML encoding of the original exercise, including the Maxima code for the generation of random parameters and coefficients in the question, and the MathML and SnuggleTeX code for rendering the question on the screen, given in Figure 3. In Figure 4, the XML code for determining whether the student's response is correct, or which (if any) of the anticipated common incorrect solutions, or some "other incorrect" solution (i.e. containing an unanticipated error) the student has entered, is shown. Figure 5 displays an excerpt from the XML code corresponding to the feedback appropriate to each of the correct and incorrect answers (including those containing the expected "common errors" and also unanticipated mistakes). Finally, what gets displayed when the student requests a hint for solving the problem is shown in Figure 6.

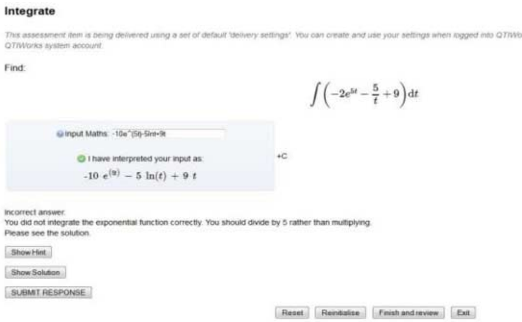

Figure 2. Example CalculEng exercise. The student has made a reasonable attempt at solving the question, but has made one of the "common errors" anticipated by the tutor who had set the question. The student then receives feedback directly relevant to the mistake he/she has made.

Figure 3. Example QTI-XML code, with interfacing to the MAXIMA Computer Algebra System, to generate a question with randomized coefficients for the particular type of CalculEng exercise, shown in Figure 1, render in using MathML, then obtain the correct solution for it.

Figure 4. Example QTI-XML and MAXIMA code, to determine whether the student's answer to the CalculEng question shown in Figure 1 is correct, is just equivalent to the mathematical expression given in the question, or the student has made one of the "common errors" anticipated by the tutor (and, if so, which error). This is then used to determine which feedback message the student should be given (see Figure 5).

```
- <div class="">
      <feedbackInline identifier="Differentiated" id="feedbackInline0" showHide="show" outcomeIdentifier="FEEDBACK"> You differentiated! </feedbackInline>
  </div>
- <div class="">
      <feedbackInline identifier="Original" id="feedbackInline1" showHide="show" outcomeIdentifier="FEEDBACK"> Your input is equivalent to the expression in
          the question. </feedbackInline>
  </div>
- <div class="">
      <feedbackInline identifier="Incorrect" id="feedbackInline2" showHide="show" outcomeIdentifier="FEEDBACK"> Incorrect - please see the solution.
          </feedbackInline>
  </div>
- <div class="">
      <feedbackInline identifier="Correct" id="feedbackInline3" showHide="show" outcomeIdentifier="FEEDBACK"> Good, you have successfully integrated the
          expression. </feedbackInline>
  </div>
- <div class="">
    - <feedbackInline identifier="Incorrect4" id="feedbackInline4" showHide="show" outcomeIdentifier="FEEDBACK">
          <br/>
          Incorrect answer.
          <br/>
          You forgot to integrate exponential function -
          <printedVariable identifier="i1overD"/>
          is missing.
          <br/>
          You also did not integrate
          <printedVariable identifier="mArg2"/>
          correctly. You forgot to multiply by a constant
          <printedVariable identifier="iB"/>
          .
          <br/>
          Please see the solution.
      </feedbackInline>
  </div>
- <div class="">
    - <feedbackInline identifier="Incorrect5" id="feedbackInline5" showHide="show" outcomeIdentifier="FEEDBACK">
          <br/>
          Incorrect answer.
          <br/>
          You forgot to integrate a constant
          <printedVariable identifier="iC"/>
          .
          <br/>
          Please see the solution.
      </feedbackInline>
  </div>
- <div class="">
    - <feedbackInline identifier="Incorrect6" id="feedbackInline6" showHide="show" outcomeIdentifier="FEEDBACK">
          <br/>
          Incorrect answer.
          <br/>
          You did not integrated exponential function correctly.
          <br/>
          Please see the solution.
      </feedbackInline>
```

Figure 5. Example QTI-XML code. Again referring to the CalculEng question from Figure 1, having identified whether the student has obtained the correct answer, or made a particular “common mistake”, the system then generates appropriate feedback for the student.

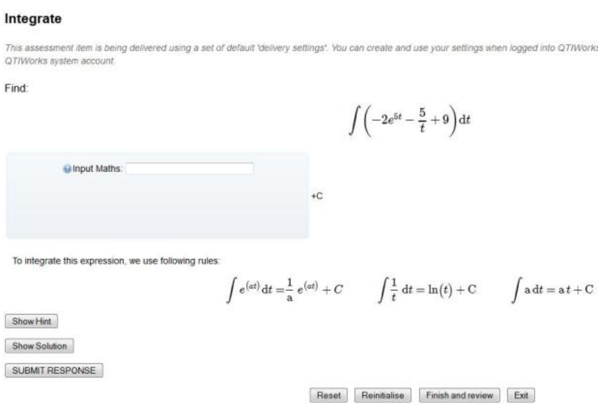

Figure 6. For the same CalculEng question as shown in Figure 2, the student has requested a hint, so the system provides useful information which should help the student solve the problem correctly.

The CalculEng system, as it stands at the time of writing, contains a good range of questions, covering the range of “standard rules” with which a first year student of mathematically-based disciplines would be expected to be familiar regarding single variable differential and integral calculus, Also included are questions on some Engineering applications of these topics – to dynamics, thermodynamics, etc. CalculEng can be accessed through a VLE system, such as BlackBoard, which enables re-use of the materials: copying questions between modules, setting formative and summative assessments and automatically grading the assessments. It is intended to extend the range of topics and examples included – for example, to cover ordinary differential equations and calculus of more than one variable, to other areas of mathematics (such as linear algebra, including simultaneous equations, vectors and matrices) and include material relevant to other application disciplines, such as economics, finance, computer graphics or computer games technology.

3. Preliminary Evaluation of CalculEng as a Virtual Tutorial Tool

It had been planned to carry out a comprehensive evaluation of CalculEng being used with students during the 2014-15 academic year. However, delays in getting the resources ready, the scheduling of parts of some modules across only parts of the academic year, plus a local restriction on surveys of students due to National and intra-institutional Student Surveys, resulted in the initial evaluation only being performed on one group of approximately 40 first year BEng Civil Engineering students, towards the end of the Spring term 2015. This period coincided with a large number of other deadlines for their in-course assessments, with the consequence that only 13 students completed the evaluation survey. The survey took place after the students had been given the opportunity of using the CalculEng system during three 2 hour supervised practical sessions. They were then given a questionnaire regarding their views on their mathematical studies, their confidence with mathematical topics and their opinions on their experience of using CalculEng. The questionnaire they were asked to complete can be found in [23].

During informal discussion, several students indicated that they believed that solving exercises on CalculEng could prove useful to them during their revision and preparation for their exams in May. They also liked the way in which CalculEng presented model solutions in a logical, step-by-step manner, and found the feedback on their answers very helpful. Quantitative results obtained from the students' questionnaire responses are shown in Figures 7 to 12 below.

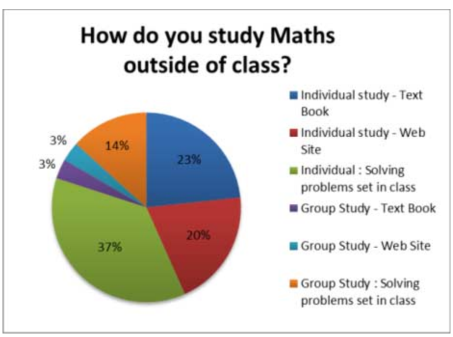

Figure 7. Student respondents' approaches to studying mathematics outside of class

As can be seen from the results in the figures, only 23% of the respondents claimed they regularly used web resources for their out-of-class mathematical studies. 51% mostly practiced exercises set in class, either individually or in groups of peers, with 26% preferring to use textbooks. The majority of the students (71%) carried out between 1 and 3 hours of individual study for the module per week, with only 15%

spending 4 or more hours per week studying for this module outside of class. Since this 30 credit module has approximately 100 hours of scheduled class time, this figure contrasts with the University's expectation that students put in 200 hours of individual study for the module, equivalent to approximately 8 hours per week !

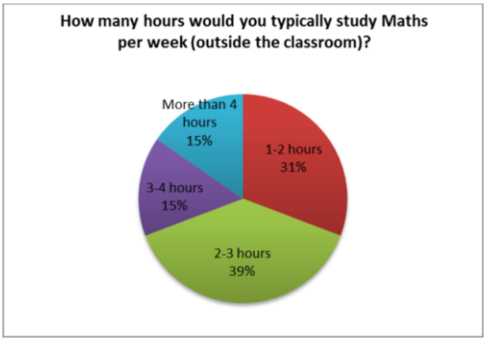

Figure 8. The amount of time per week the student respondents devoted to studying Mathematics outside of class.

Students' opinions on CalculEng were rather divided – roughly equal numbers believed that it could help their understanding of theoretical topics in calculus as did not consider that to be the case, and similarly for whether CalculEng could help them improve their time management skills when solving mathematical problems. However, slightly more students stated that they found CalculEng easy to use than disagreed with that statement.

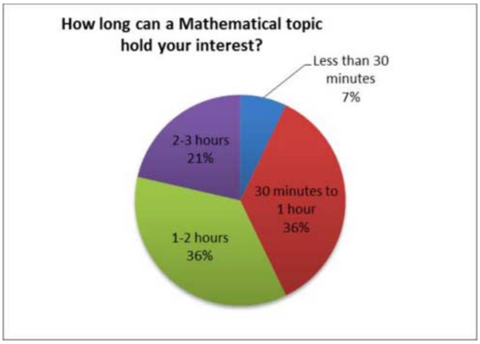

Figure 9. The amount of time the student respondents claimed that any particular mathematical topic could hold their attention.

It should be born in mind that these survey results were based on a very small sample of students, and came after those students had only had a limited opportunity to use the system. It is intended to review the on-line tutorial materials provided in CalculEng, and the questions asked to the students, before carrying-out a more comprehensive evaluation of the system during the 2015-16 academic year. This follow-up study should also allow the students more time to become familiar with CalculEng and the facilities it offers before they are expected to evaluate them.

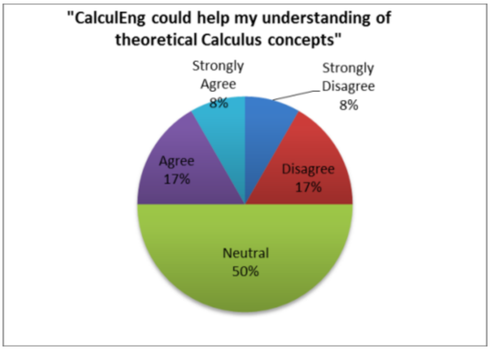

Figure 10. Student respondents' opinions on whether CalculEng could help their understanding of the theory of calculus.

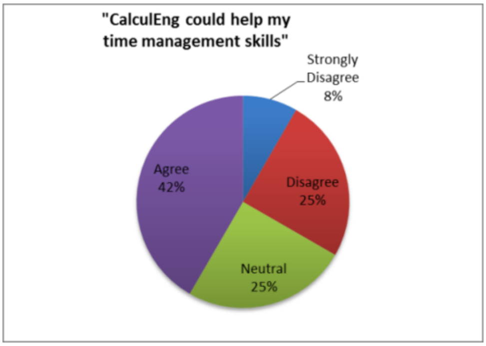

Figure 11. Student respondents' opinions on whether CalculEng could help their time management for solving mathematical exercises.

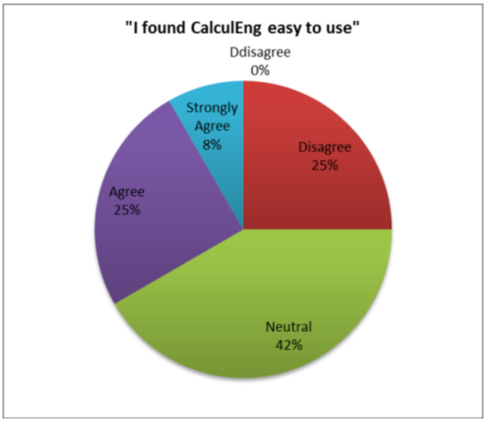

Figure 12. Student respondents' views on how easy CalculEng was to use.

4. Conclusions

In this paper, we have motivated the need for high quality, easy to use, on-line tutorial resources for mathematical topics at University level, particularly for students from “non-traditional” academic backgrounds, including disabled and mature students, who may have problems attending classes due to mobility, working or family commitments, and in accessing traditional support resources [9]. We have described our attempt at developing an on-line system, called CalculEng, for providing such resources, including exercises with appropriate feedback to the user’s answers, for students learning differential and integral calculus. We have performed an initial “pilot study” evaluation of our system on a small group of first year undergraduate Engineering degree students, and presented and discussed the results of this evaluation.

We will use the results of this evaluation to refine and improve our materials, and scrutinize the questions asked in the evaluation questionnaire, in an attempt to remove any ambiguities therein. We intend to carry out a more extensive and comprehensive evaluation of the revised CalculEng system with a larger and more diverse range of students next academic year. We will also extend the number of exercises and the range of topics which they cover and, once our resources have been thoroughly tested and evaluated, we intend to make these available to the wider community.

Finally, the “intelligence” of the current version of CalculEng is at present reliant on rules obtained from experts in the teaching of calculus, which have been “hard coded” into the XML for each question. Thus, CalculEng in its present form could be considered an “Expert System” rather than one which learns. However, opportunities exist to acquire and analyse data on what students actually do when using CalculEng – how they interact with it, what do they do correctly, and what mistakes do they make ? An example of a system which does this, but in the context of the teaching and learning of computer programming, is the NoobLab environment [20] extensively used in first year programming modules at Kingston University. Analysing and interpreting such data could, in conjunction with a machine learning system [22], enable the system to adapt the feedback rules dynamically as more evidence on students’ behaviour and errors when using the system to solve exercises is obtained. Such features could lead to CalculEng becoming a genuinely intelligent environment for providing virtual tutorial support for mathematics.

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Does the Mobile Social Software Promote the Spoken English Learning?

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Abstract. In web 2.0 era, there was little researches focused on the effect of mobile social software influencing spoken English learning in reforms of technology assist language learning. This study based on the theory of mobile micro learning and mobile learning community, a total of 72 primary school students were empirically investigated the learning outcome of using mobile social software to learn English after class for one semester. The results showed that using mobile social software to learn English after class can improve students' English speaking ability, specific performance in word accuracy, number of sentences and voice tone, and especially has significant effect on increasing the number of sentences.

Keywords. Mobile Learning; Social Software; Spoken English Learning; Empirical Study

1. Introduction

Spoken English has been a relatively weak link in second language learning (Sun, 2009). English as a second language in China, despite the attention for a long time, but has little effect on learning outcome. Nevertheless, language as a tool, the final purpose is communicating with others, so to master spoken English is the most powerful guarantee to learn a foreign language.

However, most of the students feel anxious to learn English in the classroom situation, because they are afraid to make mistakes (Cheng et al., 2010). Jakoborits (1970) claimed that the factors influencing language learning, by percentage, are as follows: aptitude, 33%; sentiment, 33%; intelligence, 20%; and other items, 14%. Furthermore, his research showed that aptitude in learning a foreign or second language is related to a learner's motivation and confidence in learning the language. Students with greater motivation and more confidence have better outcomes. In addition, students will learn from interaction and thus accumulate experience slowly but in a stable way. Significant benefits can be seen when language learning is practiced in real-life. Therefore, learning activities that simulate real-life situations can help build the pragmatic, cultural, and linguistic components of L2 competence in an integrated manner (Li, 1984).

With the advent of WEB 2.0 era, there have been a series of new social tools, such as Twitter, face book, microblog and so on, these can effectively integrate text, images, audio, video and other multimedia resources, through tablets, smart phones and other

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mobile terminal for the release of personalized information and comments. Because of its mobility and interactive, can support interactive learning under the environment of informal learning, not only can eliminate the pressure of the teachers and students face to face in the classroom situation, but also can build interactive learning platform for language exchange and learning community in a student center. Previous English as a foreign language (EFL) studies have indicated that social tools produce positive effects on English learning (Klimanova, 2013; Hwanga & Holly, 2013).

Therefore, this study selected mobile social software as experimental platform for spoken English learning experiment, exploring the learning effect of using it in an informal learning environment. Two research questions are specified as follows:

1) After using the mobile social software for English learning for one semester, will the English speaking ability of experimental class be improved?
2) In the three dimensions of speaking test, including word accuracy and number of sentences and voice tone, which part will be improved significantly?

2. Literature Review

2.1. Mobile micro learning

Mobile micro learning is a new type of informal learning that put forward in recent years. Mobile micro learning mainly meant learning short content knowledge by mobile devices at anytime and anywhere, it has two main important characteristics including ubiquitous learning and interactive learning (Chen & Li, 2008). Ubiquitous learning means learning activities can be occurred at any time and any place. Interactive learning means learners interact with expert or network server abidingly. Mobile micro learning need to combined texts, pictures, audio and video to present material and achieve interactive learning with mobile devices to meet the individual learners' needs.

2.2. Mobile learning community

Mobile learning community is based on the development of mobile communication technology and the mode of learning community, extending the theory of learning community (Hu & Ren, 2006). Socio-cultural theory reveals that language learning is not only a cognitive process but also a communication process, it should happen in the process of social individuals communicate with each other. Mobile learning community makes learning communication easier and students' participation higher, the learning process has more situational relevance. Therefore, building the learning community under the mobile technology provides learners with close communication platform and facilitates participants' communication ability.

2.3. Mobile language learning

Many mobile language projects have accumulated rich experience in the theory and practice abroad. Such as Stanford Universities in the United States, Duke University, Tokushima University in Japan all carried out the researches which used mobile technology to aid language learning, including the use of mobile phones, PDA, portable video players and laptop computers and other mobile devices in vocabulary, reading, listening and speaking teaching (Zhang & Wang, 2011). A professor of Tama University in Japan called Cathrine-Mette Mork summarizes four advantages of using social software in foreign language teaching are as follows (Mork, 2009):

- Transferring the content related to teaching.
- Sending short and timely information.
- Encouraging cooperation and feedback.
- Promoting writing language more refined.

Lamy and Goodfellow (1999) suggested that second language learners could exchange their experiences through asynchronous discussion using a computer system, and they found that this kind of reflective learning could enhance student motivation and efficiency by enabling the sharing of opinions and discussion of related subjects. Lam (2004) indicated that the communication context through virtual scene and information technology equipment was popular with second language learners, because they can express themselves more freely. Hwang and Chen (2013) showed that younger students used social software to practice speaking English with peers can promote their expression ability. Klimanova and Dembovskaya (2013) found that using social software to carry out English extracurricular activities can increase the chances of learners contact with the target language.

In light of these studies, we used social software installed on the mobile device as the English language learning tool, aiming to exploring the learning effect which primary school students use it in the after-class learning environment.

3. Method

3.1. Participants

This study selected the students of four classes in grade one in a primary school in Beijing, and then tested the English speaking ability of four class students, finally choose two classes of them as the study subjects which there was no significant difference between the test scores, experimental class (37 students) and control class (35 students). Two classes had same English teacher, lecture contents were basically identical. The only difference is that the students in experimental class used social software to complete the English homework, while the students in control classes completed the English homework without using the social software.

3.2. Social software

This study used the social software called papa, its biggest function is sharing pictures and voice. It can be installed as an app on a mobile device, the users login to the platform can share images and text with friends, and add the voice. Users also can comment the sharing content with text or voice, and click the like button to show their appreciation.

3.3. Speaking test

3.3.1. Testing method

This study tested the English speaking ability of the study subjects. Volle (2005) used articulation, accuracy and proficiency three dimensions to test speaking ability of Spanish language learners. Lys (2013) used length of lauguage sample, fluency, syntactic complexity and overall proficiency four dimensions to study the spoken English learning effect of German. Munro and Derwing (1995) used pronunciation and understandability two aspects as the measure of speaking ability. Refer to the above researches, this study used word accuracy, number of sentences and voice tone three dimensions as the measure of speaking test. Table 1 shows the specific test standard. In the dimension of word accuracy, conform to the standard 1 point, otherwise 0 point. In the dimension of number of sentences, one sentence 1 point, two or three sentences 2 points, four sentences or more 3 points. In the dimension of voice tone, conform to the standard 1 point, otherwise 0 point. The final total is 0 to 5 points.

Table 1. Standard of spoken English test.

Dimension	Standard	Score
Word accuracy	Conform to the scene content, structural integrity, and accurate.	0-1
Number of sentences	A complete description of the test scenarios.	0-3
Voice tone	Enunciate clearly, pronounce standard, and expressional fluency.	0-1
Total		0-5

3.3.2. Testing procedure

The experimenters prepared test pictures which concluded different animals, characters and scene for subjects. The subjects randomly selected one to describe the contents of the picture by English. And then the experimenters according to the test standard scored the English speaking ability of subjects. In order to test the efficiency of the social software on one semester's training, pre-test and post-test on the same subjects were carried out.

3.4. Experimental design

72 students (41 males and 31 females) participated in the experiment. 37 students are in the experimental class, 35 students are in the control class. The experiment procedure lasted from September 2013 to January 2014. Experimental class students used social software to complete the English homework after class. And the control class students used traditional method without using social software to complete English homework after class. The process of completing homework in experimental class mainly includes students using living resources to create a situation content which conformed to the topic given by teachers, and then used pictures and English voice to publish the content on the social software platform. Meanwhile the content would be commented by teacher and other students. The five steps of the experiment process are shown in Table 2.

Table 2. English learning process of experimental class and control class.

Procedure	Experimental class	Control class
Assign homework	Teacher assign the English homework on the social software platform.	Teacher assign the English homework in class.
Finish homework	Students describe the topic content with pictures and English voice.	Students complete the English homework verbally or in writing.
Hand in homework	Students publish English homework on the social software platform.	Students hand in the English homework in class.
Evaluate	Teacher evaluation and peer-assessment on the social software platform.	Teacher evaluates the English homework verbally or in writing.
Reflection	Students repeat modify the homework according to the real-time evaluate.	Unable to repeat modify the homework.

3.4.1. Teacher assigns the homework

Table 3 shows the example that teacher through the social software assigning English homework. Teacher made the English homework into pictures, and with voice published together on the social software platform. The content of homework based on the grammar patterns learned in the classroom, teacher selected a topic which conforms to the primary school English leaning content.

Table 3. The example of teacher assigns the English homework on the social software platform.

Picture	Voice
	Dear students, this is the first time we will complete the English homework on the social software platform. It consistent with the content “Our Best Days” in Unit 1. My question is: “What day is your best day? And why?” You can chose three days or more to say. Of course, don’t forget to add you pictures, okay?

3.4.2. Students complete the homework

Table 4 shows the example that students completed their homework on the social software platform. Students used physical objects of the scene of life to create English content which conform to the topic given by teachers, and then made it into pictures with voice uploading to the social software platform. Students also can conduct divergent thinking under the topic content.

Table 4. The example of students complete the English homework on the social software platform.

Picture	Voice
	I like Monday, I play basketball on Monday. I like Thursday, I ride bicycle on Thursday. I like Wednesday, I read books on Wednesday.

3.4.3. Interaction between teacher and students

On the social software platform, students were not limited to submit an English homework, but also can interact with teacher and friends. Teacher and students all applied for an account for themselves on the social software platform and then focused on each other's account. After that, teacher can see each student’s homework and give instant feedback to every student; Students also can see other students’ homework and reply comments with text or voice. In addition, teacher and students can click the “like” button to express their praise for someone’s homework. Table 5 shows the forms of interaction between teacher and students.

Table 5. The example of students complete the English homework on the social software platform.

Interactive forms	Example
Click the “like” button.	

Comments (text or voice)	

4. Results

To answer the two research questions, the t-tests were administered to compare whether there is a significant difference between scores of three testing dimensions (including word accuracy, number of sentences, and voice tone) and total between experimental class students and control class students after used the social software for one semester.

4.1. Word accuracy dimension

The results of paired t-test (see Table 6) show that no significant differences were found between experimental class and control class in word accuracy dimension (t=-1.43, p>.05). In both social software learning and traditional learning of English, there were no significant differences of English speaking testing scores in terms of word accuracy between students in two different classes (experimental class and control class). It indicated that using social software to complete English homework cannot significantly improve the English speaking ability of word accuracy.

Table 6. Results of matching paired-t test comparisons of word accuracy dimension.

Dimension	Group	Mean	SD	t
Word accuracy	Experimental class	0.97	0.16	-1.43
	Control class	0.89	0.32	

4.2. Number of sentences dimension

The results of paired t-test (see Table 7) show that statistically significant differences were found between experimental class and control class in number of sentences dimension(t=-2.37, p<.05). The experimental class scored significantly higher on ‘number of sentences’ dimension (Mean=1.46) than control class (Mean=0.86). It indicated that students got better English speaking ability of word accuracy in the social software than traditional self-learning environments, students used social software to complete English homework can significantly improve the English speaking ability of number of sentences.

Table 7. Results of matching paired-t test comparisons of number of sentences dimension.

Dimension	Group	Mean	SD	t
Number of sentences	Experimental class	1.46	1.17	**-2.37***
	Control class	0.86	0.97	

* p<.05

4.3. Voice tone dimension

The results of paired t-test (see Table 8) show that no significant differences were found between experimental class and control class in voice tone dimension (t=-1.79, p>.05). In both social software learning and traditional learning of English, there were no significant differences of spoken English testing scores in terms of voice tone between students in two different classes (experimental class and control class). It indicated that using social software to complete English homework cannot significantly improve the English speaking ability of voice tone.

Table 8. Results of matching paired-t test comparisons of pronunciation dimension.

Dimension	Group	Mean	SD	t
Voice tone	Experimental class	1.00	0.00	-1.79
	Control class	0.91	0.28	

4.4. Total of three testing dimension

The results of paired t-test (see Table 9) show that statistically significant differences were found between experimental class and control class in total of three testing dimensions(t=-2.63, p<.05). The experimental class scored significantly higher on total (Mean=3.43) than control class (Mean=2.66). It indicated that students got better English speaking ability in the social software than traditional self-learning environments, students used social software to complete English homework can improve the English speaking ability, specific performance in three dimensions including word accuracy, number of sentences and voice tone. After used social software for English learning for one semester, the English speaking ability of experimental class students were at a higher level.

Table 9. Results of matching paired-t test comparisons of total.

Dimension	Group	Mean	SD	t
Total	Experimental class	3.43	0.20	**-2.63***
	Control class	2.66	0.22	

* p<.05

Fig 1 shows the comparison of the mean value about three dimensions and total, it can be seen that the mean value of three testing dimensions and total of experimental class are all higher than the control class. This also shows that social software can promote students' spoken English ability.

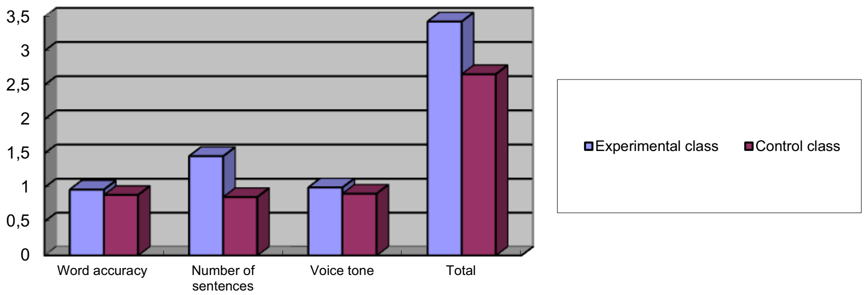

Figure 1. The comparison of the mean value about three dimensions and total.

4.5. Interview

In order to complement the quantitative results, an interview was carried out to the subjects at the end of the experiment. The interview mainly includes four Semi-structured open questions which consult the outline of interviews that used to investigate the applications effect in education of modern information technology (Hall & Higgins, 2005; Sad & Özhan, 2012). The questions are as follows:

1) After used social software for English learning, what's your favorite function about it? And why?
2) After used social software for English learning, what's your least favorite function about it? And why?
3) How the social software help you in the improvement of spoken English ability?
4) What are your ideal information learning tools?

Based on the analysis of interviews, the application realizations of using social software are mainly embodied as follows:

- Students are willing to use social software learning English after class, because they can communicate with teacher and peers, and obtain the real-time evaluation of others.
- Social software can improve students' English learning motivation, because they can share their pictures and sounds to express their own ideas on the platform.
- Students are willing to practice in advance before submitting assignments, and then publish the best one on the social software platform.
- Students think that social software can increase the chances of learning English, because they add more words and sentences and speak more fluently after use it for one semester.
- Except the homework, students are willing to publish their personal details in English on the social software platform.
- Some students need to seek help from parents to use the social software.

- Students feel rejection for the technical defects of mobile devices, such as crash, slow on, slow response, grainy photos and so on.

5. Conclusions and discussion

This study assessed 72 primary school students, through a comparative research exploring the English learning effect by using social software installed on the mobile devices. Experimental procedure lasted for one semester, mainly concluded experimental class used social software for English learning after class, and control class leaned English after class without using the social software. It's worth mentioning that in order to control some factors can affect students' learning outcomes, experimental class and control class had the same English teacher, and teaching contents were basically the same. The speaking test results showed that students in experimental class improved English speaking ability compared with the students in control class, and they especially significantly increased the speaking ability of number of sentences. Therefore, this study concluded that using social software for English learning can improve English speaking ability, specific performance in three dimensions including word accuracy, number of sentences and voice tone, and especially has a significant effect on increasing the number of sentences.

Krashen points out that foreign language learning anxiety in classroom situations is associated with learning failure, such as afraid of making mistakes, afraid of losing face, and afraid of teacher criticism and so on (Li, 2009). Students use the social software after class, avoiding the nerves of teacher and students face to face, and relaxed learning environment has a positive effect on increasing interest in English, students become more attention to English learning. In addition, social software set up a digital communication network for whole class students and teacher, they can interact with each other instantly. Students' English homework published on the social software platform not only can get comments from classmates, but also can be evaluated by teachers, therefore, students have higher motivation and more willing to invest in doing English homework. Otherwise, in after-school learning environment, students use the resources in the real life to create homework content and every English word can be found the prototype around them, they learn and use English in a real situation. English learning becomes more relevant to social situation. Therefore, compared with the traditional learning methods in class, using social software for English learning after class has added advantages of improving English speaking ability.

Lys (2013) investigated the use and integration of iPads in an advanced German conversation class, found that the additional practice afforded by using an iPad indeed increased the amount and quality of the oral production, and getting involved in real-time conversational activities is likely to be beneficial in helping improve oral proficiency. In this study, we also found that social software can promote the amount of spoken English production, mainly manifest as increased the number of sentences. Kumaravadivelu (2006) noted the language output depend on the internalization language. Therefore, through social software creating language environment can enlarge the input of the target language through practical methods, to promote the internalization of language rules, to cultivate language sense.

Some limitations need to be pointed out. Perhaps there were some uncontrollable factors affect the validity of experimental results, such as history, maturation, testing, interaction of setting and treatment and so on, so findings would be disturbed by these factors, so as to have certain negative impact on the generalization of conclusion. Future study can through a better documented control strategy evading these factors.

Acknowledgment

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A Needs Analysis Survey for Open EAP Courses for Chinese Graduates on Overseas Exchange Programs

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Abstract. This paper reports a Needs Analysis survey done on Chinese graduate students majoring in science for an open English for Academic Purpose (EAP) course design. By conducting a survey about the sample group, the researchers attempt to discover graduate students' needs, difficulties, and study habits in English learning, what contents and skill instructions should be included in an online EAP course and how designers and instructors can better involve students in online EAP learning activities. This preliminary Needs Analysis research may provide a basis for innovative online EPA courses design and delivery, and help the selection and preparation of open EPA educational resources.

Keywords. open education, open course design, needs analysis, quantitative survey, English for Academic Purpose (EAP)

1. Introduction

Researches on English for Academic Purpose (EAP) theories (Dudley-Evans & St John 1998; Jordan 2010; Dudley-Evans 2011) and teaching practice in Chinese universities are gaining momentum in the past five years (Cai 2012; Shu 2014). Many government-funded incubating projects are now launched to boost the development of EAP courses and programs in the hope to improve the international communication abilities of future Chinese academic researchers. Since 2012, the emerging trends of massive online open courses and small scale private online courses have been attracting the attention of both Chinese educational professionals and authorities because this new and exciting online teaching and learning approach (Wang 2006, 2007; Hastings & Tracey 2004; Fox, Patterson & Ilson et al., 2014) may bring new light to the nation-wide EFL reforms in China (Yuan & Liu 2014). As the Chinese government plans to send 8000 graduate level science students abroad to pursue doctorate degrees or to join exchange doctorate programs, while not every domestic university has the teaching resources of EAP, the authorities are now considering cross-university online open course projects aiming at providing open EAP courses and open education resources for these students (Cai 2012; Shu 2014; Gong & Shi 2014). Researchers are now working on the needs analysis, course book and teaching mode design (Mackey & Gass 2012).

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Under this background, this paper focuses on a needs analysis survey done for an online EAP course design in a university overseas language training center with 113 subjects of Chinese postgraduates and doctorate candidates from all over the country. The purpose of this survey is to find out: 1) the needs of postgraduate level students for EAP, 2) current and potential difficulties in their English academic studies, 3) students' expectations and preferences for online EAP learning and teaching activities. Such surveys are considered by the researchers as timely and necessary because needs analysis is like a diagnosis before prescription in EFL education (Brindley 1989; Long 2005:1). The understanding of graduate students' learning motivation, competence level, learning habits and their expectations for an online EAP course would provide support for the innovative open EAP course design, delivery and development.

The descriptive survey reported in this study attempts to discover the preference and demand for open online EAP courses of the Chinese postgraduate level learners, to what degree students accept online learning as an instructional option, and how designers and instructors can better involve students in open EAP learning activities. The results of the survey can be useful for the innovative open EAP course delivery, course material development, and online learning activities design.

2. Participants and theoretic basis

This current survey targeted a group of graduate level students who are on a government funded "China Scholarship Committee supported Overseas Academia Exchange" project, which is part of the national educational five-year plan for developing high-level Chinese universities. These students are candidates from different universities all over China who were on a two-week intensive English training course in Shanghai International Studies University from January 12 to 27, 2015. The survey design is based on the English Learning Needs Analysis model by Dudley Evans &St John (1998) and Chen (2010). This modal consists of four needs' analysis dimensions, namely individual learner competence differences, individual learner motivations, learning process demands, and learning environment demands.

Survey questions regarding these four dimensions mainly focus on 1) Individual learner differences such as current English learning situation, self-assessment about English competence, learning difficulties, etc.. 2) Individual learner motivations such as the willingness and eagerness in improving English levels, learning motivations and goals. 3) Learning environment demands such as the needs for in-class settings including class forms, teaching methods, class activities, class length preference and assessment preference, etc. 4) Learning process demands such as learning strategy, interest, attitudes, study habits.

3. The Preliminary survey

For the survey design, the researchers firstly based their draft question items on the widely adopted English Learning Needs Analysis model by Dudley-Evans & St John (1998) and Chen (2010). And then they talked with four other EFL teachers (2 Chinese native and 2 English native teachers) in the department about the questions and with their written feedback worked out a trail questionnaire. After that, a pre-test for the survey was carried out with a 40-student class. Based on the pre-test survey and analysis, the researchers modified some question items. Thus for the survey proper, each individual question item reliability was with a Cronbach's Alpha index over 0.790.

The researchers used classroom time to ask 128 students in their classes to do the survey and 113 valid responses were collected. All the raw response data were put into the SPSS software to conduct a descriptive analysis. Altogether there were 45 questions in the survey. Except for the demographic information questions and multiple choice questions concerning the students' personal information, learning experience, self-assessment and expectations, all the other questions (translated into English from Chinese) as shown in table1 were presented on Likert Scale format.

As the survey was conducted to gather data for an innovative online EAP course, the researchers wanted to find out information about some practical course design questions. First, what English contents and skills would the course focus on so as to help graduate students to improve their academic English related language abilities. Second, the researchers aimed at seeking information about the online course teaching format and class activities that the students would prefer. Third, questions were asked concerning the students' learning strategies and habits for the purpose of online course learning task design. Fourth, the researchers also asked questions related to the students' habits of and preferences to internet based English learning. This data analysis may help future students, researchers, administrators, and faculty to determine if an online EAP course meets their needs. The data analysis results are presented in the next section.

3.1. Data analysis

The SPSS descriptive analysis indicated that the sample was composed of 53.98% male students and 46.02% female students, with the 20-25 age group taking up 38.05% and the 25-30 age group accounting for 58.41%. Their educational backgrounds were largely doctorate candidates (89.38%) and the rest are all postgraduates. 90.27% of the 113 students major in natural science majors. The expected future career fields of these subjects were teaching practice (20.35%), theoretical and /or lab research (62.85%) and company business (11.50%). 95.58% students had English learning experience of a minimum of 9 years.

When all the raw responses were collected, the researchers put the data into the statistical analysis software SPSS for a descriptive and factor analysis. Table 1 and table 2 below show the data analysis output.

Table 1. Descriptive Analysis for Likert-scale questions

Question number	Question Text	Minimum	Maxi-mum	Mean		Standard deviation
		Statistic	Statistic	Statistic	Standard error	Statistic
11	Learning English is very important because it is a useful communicative tool	1	3	1.27	.047	.500
13	Learning English well can help me in my international communication with foreign counterparts	1	3	1.32	.049	.522
14	Learning English well can help me in my future promotion in career	1	3	1.58	.061	.652
18	My tutor often asks me to do academic literature reading and reviewing in English	1	4	2.88	.042	.446
23	Using English in doing literature review is important to me	1	2	1.14	.033	.350

24	.It is important to write abstract, literature review, experiment report and papers in English.	1	5	1.24	.051	.539
26	I am satisfied with my English abilities in my work and studies.	1	5	3.30	.072	.766
27	What I need is separate skill courses in General English Reading, Writing, Speaking and Listening.	1	4	1.68	.075	.794
28	What I need is integrated courses of General English Reading-Writing, and Speaking-Listening.	1	4	1.63	.061	.644
29	What I need is separate skill courses in Academic English Reading, Writing, Speaking, and listening	1	5	1.95	.083	.885
30	What I need is integrated courses of Academic English Reading-Writing, and Speaking-Listening.	1	3	1.75	.062	.662
31	What I need is separate skill courses in both general and academic English Reading, Writing, Speaking and Listening.	1	4	1.89	.074	.783
32	What I need is integrated courses of both General and Academic English Reading-Writing, and Speaking-Listening.	1	4	1.81	.064	.680
33	What I need is a test-oriented course for TOFEL, IELTS, PETS and MOE tests.	1	5	2.26	.092	.980
34	I would like to have my English classes in the form of a teacher-centered lecture.	1	5	2.68	.101	1.071
35	I would like to have my English classes in a task-based, teacher-guided, and student-participated interactive mode.	1	4	1.72	.066	.700
36	I would like to have my English classes in the form of student-centered seminars.	1	5	2.10	.078	.834
37	I would like to have a mobile English class on the internet.	1	5	2.27	.083	.887
38	I would like to use internet classes to do research, check homework and have teachers' feedback.	1	5	1.96	.066	.699
39	I think the question-and-answer activities are every effective teaching method in class.	1	4	1.85	.058	.616
40	I think the group project activities are every effective teaching method in class.	1	4	1.86	.056	.596
41	I think the activities with a demo by the teacher or a student first and then followed by individual practice by student themselves are effective teaching method in class.	1	4	1.88	.059	.623
	VALID N 113					

After this descriptive analysis, the researchers carried out a further factorial analysis for the 22 Likert-scale questions to find out the common factors of these questions. The factor analysis revealed that the questions fell into seven dimensions and these can be further classified into the four main dimensions as presented in the next section of Survey Results.

Table 2 The Rotating Component Matrix of Factor Analysis for Likert-scale Questions

	Components						
	1	2	3	4	5	6	7
I would like to have my English classes in a task-based, teacher-guided, and student-participated interactive mode.	.783						
I think the group project activities are every effective teaching method in class.	.766						

I think the question-and-answer activities are every effective teaching method in class.	.684						
I think the activities with a demo by the teacher or a student first and then followed by individual practice by student themselves are effective teaching method in class.	.626						
I would like to have my English classes in the form of student-centered seminars.							
Learning English is very important because it is a useful communicative tool		.799					
Learning English well can help me in my international communication with foreign counterparts		.754					
Learning English well can help me in my future promotion in career		.679					
Using English in doing literature review is important to me		.658					
What I need is separate skill courses in Academic English Reading, Writing, Speaking, and listening			.850				
What I need is separate skill courses in General English Reading, Writing, Speaking and Listening			.820				
What I need is separate skill courses in both general and academic English Reading, Writing, Speaking and Listening			.761				
What I need is integrated courses of both General and Academic English Reading-Writing, and Speaking-Listening.				.837			
What I need is integrated courses of Academic English Reading-Writing, and Speaking-Listening				.836			
What I need is integrated courses of General English Reading-Writing, and Speaking-Listening.				.806			
I would like to use internet classes to do research, check homework and have teachers' feedback					.866		
I would like to have a mobile English class on the internet.					.860		
I am satisfied with my English abilities in my work and studies						.649	
My tutor often asks my to do academic literature reading and reviewing in English						.623	
.It is important to write abstract, literature review, experiment report and papers in English						-.579	
What I need is a test-oriented course for TOFEL, IELTS, PETS and MOE tests.							.830
I would like to have my English classes in the form of a teacher-centered lecture.							.719

3.2. Survey Results

With the results from the descriptive and factorial analysis, together with the frequency output of other non-Likert questions, the researchers were able to work out the needs related information about the sample graduate English learners. The results were interpreted in the following four aspects.

- I) Individual learner differences
- 2) Individual learner motivations
- 3) Online learning environment demands
- 4) Online learning process demands

3.2. 1 Individual learner differences

The research reflected that the sample students shared some similar features in terms of their current English learning situation, English competence self-assessment, and learning difficulties. First, only 2.65% of all students felt strongly satisfied about their English competence. 53.98% of them found themselves just adequate in English abilities and over 1/3 of the responds were unsatisfied or strongly unsatisfied about their English levels. The weakest English skills were English listening, speaking and writing. The following charts illustrate the English skills that the students wanted to improve in the next two years.

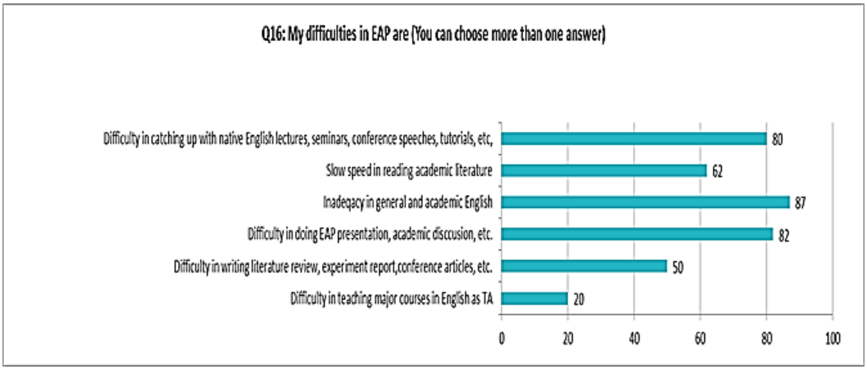

Figure 1. Students' self-assessment of EAP learning difficulties

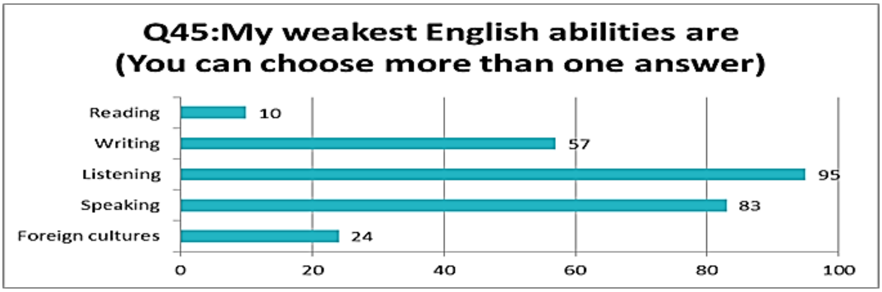

Figure 2. Students' self-assessment of their weakest English abilities

All the 113 subjects thought it very important to improve their academic English reading abilities as their tutors often asked them to read English papers, articles and books in their major fields. Although only 69.91% of students were asked to write some abstracts, literature review, experiment reports and research papers in English, 99.15% of the sample group believed that it was very important for them to have the knowledge and skill in academic English writing. The following charts provide information about the common difficulties shared by the 113 students.

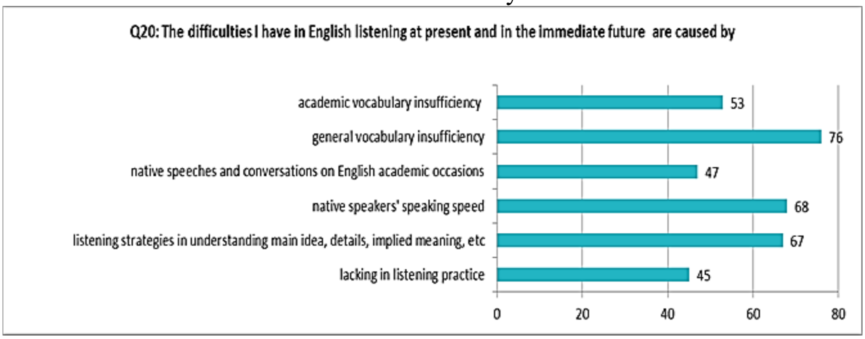

Figure 3. Students' difficulties in EAP listening at present and in the immediate future

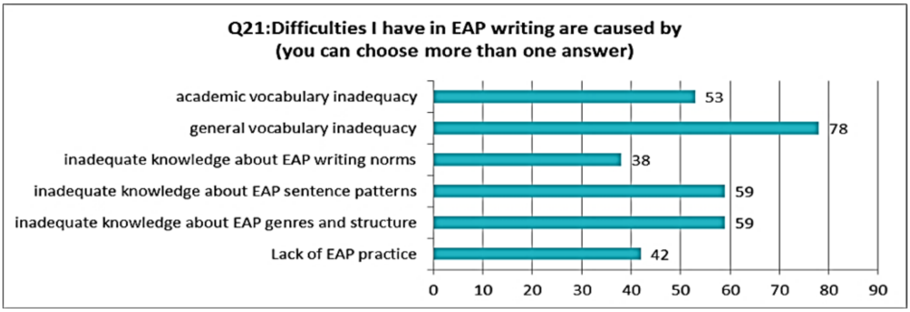

Figure 4 Students' difficulties in EAP writing

3.2.2. Individual learner motivations

Individual learner motivations such as the willingness and eagerness in improving English levels, learning motivations and goals were studied by questions designed for this dimension. The research revealed that the sample group showed common instrumental motivations rather than integrative motivations in their English learning needs.

These learners felt that their English demands at present and in the immediate future were to understand the foreign scholars' lecture or seminars (101/113) to write their research abstracts, literature reviews, experiment or research reports and dissertations in English (97/113), to communicate fluently with their international academia counterparts (96/113), to give presentations in class and on academic conferences (95/113), and to read academic English articles, reports, books (94/113). Other English facilitating needs include taking English or bilingual courses in their majors (44/113), teaching the major courses in English (28/113), and doing business in English (20/113).

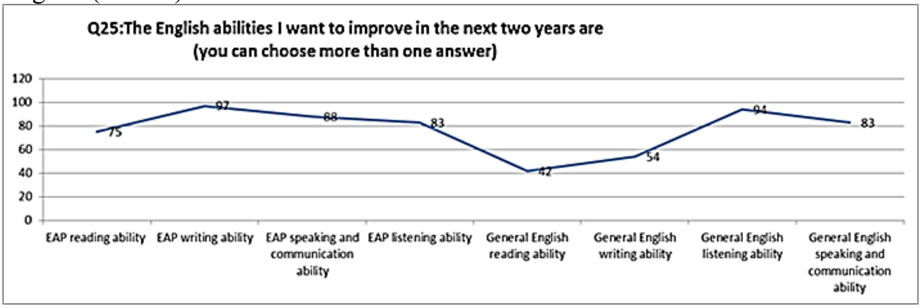

Figure 5 English abilities that students want to improve in the next two years

3.2.3. Online learning environment demands

Questions of online open EPA learning environment demands included items asking for information concerning the needs for in-class settings including class forms, teaching methods, class activities, class length preference and assessment preference, etc. The survey showed that students in the sample showed strong interest in their expectations about the open English courses, regardless of English for general or academic purposes. There was also no apparent preference to the English related subjects. Interestingly, it was found that no matter what the content of the open EAP courses would be, whether it be listening, speaking, reading, or writing, the students expressed similar enthusiasm degree with the Strongly Agree and Agree categories occupying large proportions ranging from 87.1% to 94.9%.

Concerning the open online course class formats, the study showed that the graduate level students no longer felt satisfied with a solely teacher-centered lecture class, but rather preferred a class where they could participate in and interact with the instructor and fellow students. The survey indicated that the sample group had a highly positive attitude towards English classes in a task-based, teacher-guided, and student-participated interactive mode with over 91% responds voting for Strongly Agree. Class activities such as Q&A's, group projects, and demo-first individual work were popular among the sample group students. Following figures give information about the class activity preferences.

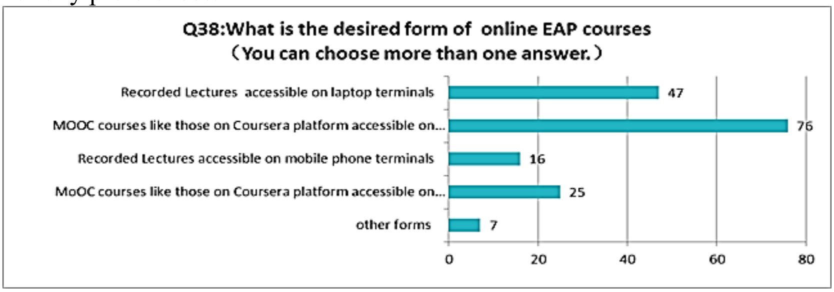

Figure 6. Students' desired form of online EAP courses

3.2.4. Online learning process demands

Questions in this dimension concentrated on issues such as students' individual learning strategy, interest, attitudes, study habits, etc. As shown in the research, the sample student group had relatively strong independent learning abilities. The commonly applied independent learning strategies included audio strategy (such as to practice their listening through dictation, intensive listening exercises, English movie, drama series and other programs viewing, etc.), reading strategy (such as academic and fictional literature reading, Google scholar search engine research, etc.) , communication strategy (such as to talk with foreign friends and academia counterparts). For these Chinese students, it seemed that the Reading and Audio Strategies were still the major learning strategies. Although the emerging multi-media and internet resources were widely used by the subjects, their utilization of the internet was still concentrating on research engine inquiries, reading academic literature, receiving and completing homework, transferring study materials, sharing test materials, watching movies and drama series, listening to English songs. The internet based laptop or mobile English courses were either not available or not to the knowledge of these Chinese students. The following figures illustrate the graduates' expected open session length and learning strategies.

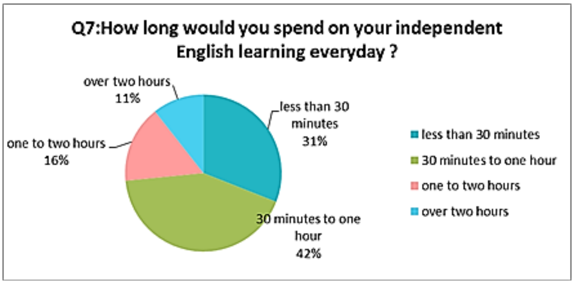

Figure 7. Students' preference of independent daily online EAP learning length

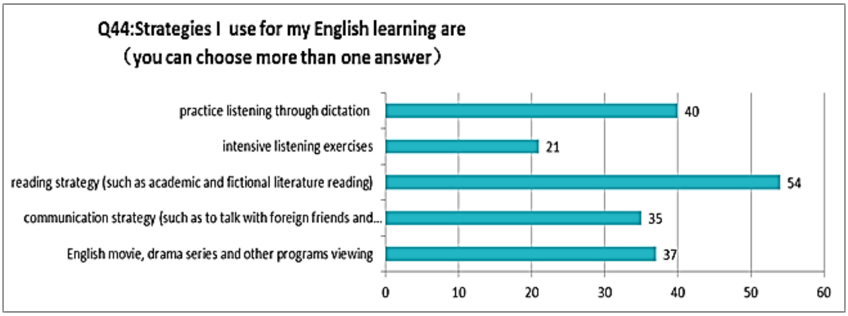

Figure 8. Students' preference of strategies in English learning for the online EAP courses

4. Conclusions and Recommendations

This preliminary survey was conducted for the purpose of providing relevant practical information for future online EAP course design and implementation for graduate level Chinese science students. It was the researchers' hope that the results of this statistic needs analysis survey may imply some suggestions for innovative online course delivery, open educational resources' presenting format selection, and online activities design for independent open learning. And EAP course developers, researchers and instructors could have some statistic survey to refer to when making their choice of teaching materials, content and skill focuses, online class presentations, online class activities, etc.. Some recommendations are proposed as follows regarding an online EAP course design.

Open EAP course length and genres: The graduate level EAP online course may be better received by students if each of the online class session lasted 30-40 minutes with another 10 to 30 minutes for individual practice. It would be best if the total length of the course is not to exceed two months with two to three sessions weekly. Considering the attention span of graduate students as indicated in the survey, each 30 minutes' session may well as be segmented into 2 to 3 smaller sections in order to keep the students alert and concentrated. According to the needs analysis, students would need more of EAP speaking, listening, and writing courses than reading or foreign culture related course. It would be more practical to provide separate online EAP courses focusing on each of the four subjects instead of a single ambitious comprehensive EAP course. It may also be good to divide the EAP courses into different level modules so that the students can either choose their courses according to their own competence level or continue from a lower level to another higher one.

Open online Course contents: In terms of the EAP open course content design, it would be advisable for developers to include not only general English but also common science vocabulary input, and phrasal and sentential expression input for listening, speaking and writing courses. More native materials rather than modified teaching materials would be better received by the students. For example, for the open EAP listening and speaking courses, real scenarios such as recorded lectures, conference speeches, presentations, and seminars may be more inspiring for the graduate level students because the real academic audio-visual materials would create a relevant and immediate foreign learning environment for the Chinese graduates.

It would be also advisable to include important listening strategies for main idea, details, and implied meanings in online EAP listening course sessions. It can also be essential to cover speaking skills of making public speeches, making classroom and conference presentations, discussion norms, and right pronunciation, intonation and stressing patterns in the EAP speaking course sessions.

As for the writing course, EAP reading materials can be integrated into the writing course. Besides the academic writing norms such as the academic article, books, theses, literature review, conference papers, tables and graphs, etc., the students would probably embrace some inspiriting instructions on academic English sentence patterns, grammar and vocabulary.

Open O*nline course activities and feedbacks:* In designing online open EAP course activities and student practices, diverse forms such as the Q&A exercises, group discussion, role play, small project completion, and individual practice with the demo of the instruction or a fellow student can be put on the option list. The key point is the interactivity between the mobile terminal and the individual learner, between the peer, and between the student and the instructor inside and outside the online course sessions. Students' forums with peer sharing, group identification, timely feedback and help from some tutors or some experienced and high-level fellow students would be valuable and necessary to discover and solve learning problems in content, learning strategies and skills, and homework completions.

The students can also benefit from a peer group social community with the open course. Online study group forums, Wechat or Facebook discussion groups, homework discussion forums, and local real-life study groups can be formed so as to create a social network for the open course participants. Topic based reading seminars, homework exercise discussions, simulated small science project presentations and reports could be activities for the open EAP course participants in accordance with their independent learning ability and study habits.

At this stage, the researchers also recognized some limitations to this research. First, some dimensions were not included in this survey about the online open EAP course assessment mode such as the peer/instructor assessment and test formats. Second, there could have been more specific questions concerning students' awareness and attitudes towards some foreign MOOC or SPOC platforms and courses so that a Chinese students' preference can be implied. Third, more detailed questions about the expected differences between an online course and a classroom course should be asked in the future studies. It would also be insightful if further surveys and studies are conducted to find out teachers' attitude and beliefs about the innovative delivery of open online EAP courses.

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Motivational Influences in a Transnational Music Virtual Studio: A Qualitative Case Study

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Abstract. A science of e-learning involves the scientific investigation of how people learn in electronic learning environments. This paper reports about experiments carried out with OPEN SoundS, which is a musical environment designed and developed as a virtual studio where students and teachers from all over the world, can create collaborative musical projects. The main aim is to uphold a strong level of motivation. The results are two-fold: firstly, students achieved better results in the area of music technology and in the area of theory, analysis and composition; secondly, e-learning strategy is superior to the traditional learning method in terms of learning motivation.

Keywords. e-learning, learning motivation, music education, music technology, OPEN SoundS, technology enhanced learning

1. Introduction

The fast development of information systems and the Internet technology not only makes a lot of progress in multi-media and the Internet industry, but it also affects innovation in the educational learning style: learner and educator will confront new teaching and learning methods [1].

Computer assistance learning with websites combines into The Internet learning. The learning method will improve one way or another from static to active. With e-learning, the learner and teacher can be in different places and interact at different times.

E-learning is a platform with flexible learning using Information and Communication Technology (ICT) resources, tools and applications, and focusing on interactions among teachers, learners and online environment [2]. In e-learning, the teacher's role is guidance. Teachers are not in the role of explaining course content. And the learners become more active. Therefore, e-learning changes the responsibility of learning from teachers to learners [3]. According to Rani [4], Internet is an ideal tool to stimulate self-learning instruction. Self-directed learning online is a learning resource that can foster a desire for students to learn independently and to strengthen the students "level of motivation" [5].

The benefits of using ICT in the educational process reside both in the various instruction opportunities it can offer, and in the transformation of relationships between students, teachers and the learning equipment: unfortunately, researches have shown that the use of computers in music classes (in the high school) seems less common [6].

Recently, scientists have been studying not only the influences of encouraging learning environments but, above all, the influences of learning in diversified learning environments [7].

In these new learning environments, for a teacher is difficult to identify connections between learning and motivation: motivation influence learning and learning brings changes to motivation [8].

In this paper, we report a case study conducted with students belonging to music courses in the Music High School in Italy and at the Escuela Universitaria de Magisterio de Segovia in Spain. The course offered a blended learning course to improve the learning of music composition using the computer environment *OPEN SoundS*. The aim is to investigate the students' effective behaviors, as well as to understand the different types of intrinsic and extrinsic motivation in e-learning.

This paper is organized as follows. Section 2 describes the motivation to learning. Section 3 describes the computer environment OPEN SoundS. Section 4 shows an experimental test that illustrate the effectiveness of the proposed method and finally, conclusions are drawn in Section 5.

2. Motivation for learning

Motivating students is one the most difficult parts of being a high school educator. Motivation is defined by psychologists as an internal process that activates, guides, and maintains behavior over time. In other words motivation gets you going, keeps you going, and determines where you're trying to go [9].

According to Brophy [10], motivation to learn is "a student tendency to find academic activities meaningful and worthwhile and to try to derive the intended academic benefits from them".

Therefore, we wonder: what research constructs explain students' motivation to learn in general (music) education programs?

The constructs can be viewed as belonging to three categories [11]:

1) constructs that refer to students' traits and states, such as interest and curiosity: students in general education programs who are interested or curious about topics are oriented toward inquiry and discovery, both of which are instructionally desirable;
2) constructs that refer to students' beliefs, such as self-determination (the ability to make choices and have some degree of control in what we do and how we do it [12]), goal orientation (an objective or outcome that students pursue, is a goal why students pursue it is referred to as their goal orientation, and the result is goal-directed behavior [13]), self-regulation (students who are self-regulating know what they want to accomplish when they learn: they bring appropriate strategies to bear and continually monitor their progress toward their goals [14]), and self efficacy ("beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" [15]);
3) constructs that refer to students' expectations: expectations of students, and the strategies based on these expectations, play an important role in increasing or reducing students' motivation in general education programs [16].

Motivation influences learners to choose a task, get energized about it, and persist until they accomplish it successfully, regardless of whether it brings an immediate reward. Motivation is present when learners actively seek out and participate in activities without having to be rewarded by materials or activities outside the learning task.

3. OPEN SoundS

OPEN SoundS is a Leonardo da Vinci (TOI) project that offers a new dimension in training on the Net: the possibility to produce and share music remotely within communities (a transnational virtual studio).

OPEN SoundS' main commitment is to transfer to the students, from all over the world, the tools and practices, as well as the processes associated with a collaborative and remote use of digital music technologies. In particular, the goal is to test the extension of a model of informal learning, and its integration in a creative key, into educational paths/processes meeting the expectations of both the society of knowledge and information, and the individual educational and vocational needs of students.

In terms of expected results, the project wants to allow students attending education and vocational training in the partner countries, with special attention to the risk of school-leaving, to:

- build the first structured European training network to develop creative music projects with collaborative, remote and transnational features;
- develop digital and technological skills;
- strengthen the sense of active citizenship through collaborative practices which will involve a significant number of young music enthusiasts in the partner countries;
- increase the possibilities, the quality, the chances and the areas of transition in terms of job opportunities.

The OPEN SoundS Community is a meeting point for students and the various actors involved in the creation of music in a collaborative, remote and transnational dimension. The community involves:

- students from schools, music academies, universities, research centres and relevant networks (school, producers and/or artists networks);
- students from public and private vocational institutions;
- teachers from the various music education areas;
- musicians and other operators from the communication industry (cinema, TV, advertising);
- community of music ICT professionals and software developers;
- companies involved in the multimedia supply chain and, in particular, in electronic music (specialized manufactures of music computers and software).

OPEN SoundS is a virtual learning environment dedicated to the creation of music: shared support tools are provided to act within it.

The networks of interest in this area are related to:

- the development of creative musical products;

- skills around the operation of technological equipment (software and hardware) for the production and creation of music;
- the acquisition of more general skills related to collaborative learning environments.

Through OPEN SoundS students and teachers can:

- access a virtual learning environment dedicated to collaborative music production which functions remotely and transnationally;
- work with students from all over the world to create and share music remotely within the education system;
- access training and information resources for the conscious and strategic use of digital music technology and the Net.

The OPEN SoundS collaborative system is a virtual community where students and teachers can create collaborative musical projects through a two-step process, which provides:

1) the creation of a content of type "idea" which illustrates the initial idea of a project by a descriptive text, giving way to other students to intervene in the discussion and form a project team (*Create Idea*); A list of all project ideas is always accessible to view the ideas proposed by other students before proposing new ones (*List of New Ideas*);
2) the group starts to create a content type "project" (*Create Project*), that means, a collaborative music production in a dedicated environment that allows to:
   - describe the musical project in every aspect, cultural and technical;
   - upload any type of music files necessary for its implementation;
   - view the tracking of the contribution to the final production provided by each student team;
   - post and view comments about the creative productions.

In the mentioned *Create Project* environment, is possible to upload any type of music files and more precisely all types of audio and MIDI files, samples, as well as Scores, Patches and Schemes of composition. At any time is possible to see every aspect of the project: description, specifications, used files, individual contributions and posts.

OPEN SoundS, through a highly innovative and creative practice in fact wants to be a means to stimulate and support for the development of key competencies for initial and continuing training.

4. Application and analysis

The method proposed in this article consists in the use of the computer environment *OPEN SoundS* in order to improve the performance of students in the area of theory, analysis and composition.

The research was carried out within a period of four months (from October to January 2015) and it involved 20 students: 10 students enrolled in the fourth and fifth grade of the Music High School of Castelfranco Veneto in Italy and 10 students enrolled in the second year at the Escuela Universitaria de Magisterio de Segovia.

The subject proposed to the students consisted in the realization of a commercial starting from the written text related to the narrator voice: the students had to record the narrator voice, write the music texts, record them and join them to the voice.

OPEN SoundS is a very versatile platform and it does not require the use of a specific technology, quite the opposite, it is possible to define, for every project, what technologies to use. For the specific project at hand, knowledge of the following software was required: Audacity or ProTools for the audio editing, Finale MakeMusic for the editing of music scores and Max/Msp for the realization of sound effects.

The students worked on the project through interventions that proposed every time an idea or changes/additions to a preceding idea.

The project was realized collectively by all the 20 students and was concluded at the end of January with the realization of a video.

At the end of the semester, the participants were asked to complete an online survey asking about their attitudes toward and perceptions of "OPEN SoundS" as an educational e-learning tool based on their course experiences.

The survey was made up of 40 questions pertaining to four different analysis areas:

1) ***generalization***: future applicability, other areas connection, continuing with the method, possible generalization to other courses, effects on the institution, environment;
2) ***learning effects***: acquired skills, i.e. written/oral expression, working group, decision making, critical thinking, self-confidence, learning to learn, management, languages;
3) ***actual implementation***: information about time, effort, dedication, work, required by this approach, and characteristics and criteria for implementation/evaluation;
4) ***emotional component***: satisfaction, expectations, attitudes, motivation, environment.

The students could choose, for every question, the answer among four possible answers: strongly disagree, disagree, agree, strongly agree.

In addition, the survey included three open-ended questions asking about the benefits and drawbacks of using OPEN SoundS.

Based on the results of the analysis we established a high percentage (80%) of learning contents and learning process understanding, interesting learning, adequate time planning as well as good feelings and functional atmosphere for pupils during their learning, but above all, an improvement of the performance of student.

This might be an important element to encourage learning interest. The method has shown that: firstly, the situational interest which was encouraged in pupils by mere novelties; secondly, individual interest (selecting ideas, composing music) as well as self-regulation and independent learning were well expressed throughout the entire period of research: pupils also liked the fact that learning was simple and that they were successful in learning.

From the notes of teachers' reflections we found out that there was a positive productive pupils' motivation which was expressed in their selection of more demanding tasks and in their perseverance in improving achievements and their desire to put in place new musical ideas.

In general, pupils estimated that computer aided learning is much more fun and relaxing, than "classical learning" in the classroom.

5. Conclusion

Motivation is fundamental to successful learning in general education programs. But how to effectively foster motivation to learn remains a hotly contested issue.

Students who define teacher-set goals in terms of their own reasons for learning create a commitment to a desired end-state. Their goal-setting process differs fundamentally from that of students who merely comply with the teacher's expectations.

Recent findings indicate that learning goals that are agreed upon jointly by the students and the teacher have a better chance of being accomplished. Such an agreement reflects the intention of both parties to invest effort.

Setting a learning goal refers to the selection of a motivation strategy that fits the actual learning situation. This strategy consists of active attempts on the part of the learner to activate favourable motivational beliefs, to pay attention to relevant cues in the learning environment, and to ignore cues that are distracting from learning.

Students who begin the learning process by activating favourable beliefs, particularly mastery-orientation and self efficacy beliefs, need less encouragement from others to get started. Moreover, favourable motivational beliefs draw students' attention to cues in the environment that elicit further interest and confidence in their own capacity to do the task.

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A Pilot Study of Using Mobile Platforms (WeChat and WeLearn) in *College English* Curriculum

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Abstract. Wechat, a mobile application software with functions of communication, social interaction, and platform architecture, is widely used among college students in China and has constructed a new mobile learning support environment. By analyzing the features of Wechat and Welearn and examining related studies, we discuss how to integrate Wechat-based mobile learning into the *College English* curriculum in Higher-Educational Institutions of China.

Keywords. Innovative Mobile Learning, Intelligent Social Media, College English, Wechat, Welearn

1. Introduction

College English, an integral part of higher education, is a required basic course for non-English major students in higher-educational institutions in China. According to the College English Curriculum Requirements published in 2007, the extensive use of advanced information technology should be encouraged, computer- and Web-based courses should be developed, and students should be provided with favorable environment and facilities for language learning. The new teaching model should be built on modern information technology, particularly network technology, so that English language teaching and learning will be free from the constraints of time or place and geared towards students' individualized and autonomous learning. The new model should combine the principles of practicality, knowledge and interest, facilitate mobilizing the initiative of both teachers and students, and attach particular importance to the central position of students and the leading role of teachers in the teaching and learning process.

With the advancement of technologies and the wide adoption of smart phones among the general public, the use of mobile technologies in the education sector has been fast growing. Flexible learning through mobile devices has been the trend of digital learning. Mobile learning is about using mobile devices (including mobile phones, PDA, etc) to carry out learning activities at any time and any place[1]. The integration of the mobile phones technologies and learning activities arouse students' interest during the learning process as it provides easier ways to learn, such as accessig learning materials, doing online quizzes, participating in discussions and other online activities [2].

WeChat (pronunication: Wēixìn; literally: "micro messaging") is a mobile text and voice messaging communication service developed by Tencent Inc. in China, first released in January 2011[3]. Statics shows that it is the largest standalone messaging app by monthly active users [4].

With the popularity of smart phones and Wechat among college students, a study of how to integrate mobile learning based on mobile phones into College English learning will greatly contribute to mobile learning research and College English teaching reform.

By exploring the features and functions of Wechat and relevant research, we present how to integrate Wechat-based mobile learning into College English learning, so as to help achieve student-centered, personalized and autonomous learning.

2. Mobile learning and Micro-Learning

Despite its impact on learning, mobile learning still has not entered mainstream education due to the technologic and pedagogic limitations. Mobile devices' limitations such as small screen-size, variations in platforms, mobile networks, and presentation of information to the device in a reliable and friendly manner have been identified by researchers as blocking the uptake of learning usage [5]. Micro-learning seeks to address some of these blockers and to develop a form of content delivery and user interaction which could improve on mobile learning usability. Delivering contents in long learning sequences and large chunks of information with low degrees of interactivity have limited the potential of mobile learning. By comparison, micro- learning breaks mobile learning content into small chunks with a high level of interaction and instant feedback after each user action. Learning in smaller chunks has support from learning psychology and short-term memory literature [6][7].

The basic notion of micro-learning is that people can learn better and more effectively when the content is broken down into digestible parts and learning thus takes the form of small steps [6]. This is based on human cognition theory which places the limits of processing information in short-term memory [7]. This temporal dimension, learning in small steps better fits into the human processor model of receiving information or knowledge in small homogeneous chunks [6] and fits well in the small screen size of mobile devices[8]. Micro-learning does not demand separate learning sessions but is integrated into other activities of the learner. In addition, micro-learning is good for certain types of learning environment such as informal learning, where content can be designed in smaller objects, just-in-time learning, and Web 2.0 learning. Web 2.0 technologies changes learners from knowledge consumers to knowledge producers, by enabling them to share ideas and perspectives. They can use mobile devices to log in to their social media accounts (e.g., WeChat, facebook, Twitter) and interact with others in a timely manner. They can also access mobile learning management systems such as Blackboard, Moodle, WeLearn (described below) and even a Massive Open Online Course (MOOC). However, researchers and practitioners all discovered that mobile learning may not be appropriate of all forms of learning and therefore it compliments (does not replace) learning that requires face-to-face interaction or hands-on practice in a controlled setting (e.g, lab experiment).

3. Features and Functions of Wechat

Wechat app is available on almost all smart phones including Android, iPhone, BlackBerry, Windows Phone, and Symbian phones.

3.1. Basic Functions

WeChat provides text messaging, hold-to-talk voice messaging, broadcast (one-to-many) messaging, sharing of photographs and videos, and location sharing as well as group chat. It can exchange contacts with people nearby via Bluetooth, as well as providing various features for contacting people who are physically nearby and integration with social networking services such as those run by QQ, another popular social media developed by Tencent. Wechat is based on the user's QQ friends list and their cell phone contacts lists, which are convenient and effective ways of building circles of friends. Users can quickly build a social network circle in a short period of time.

3.2. Public Platform

WeChat has built an ecosystem based on its Public Accounts. Apart from communicating with subscribers and sending them multi-media messages, Public Account owners can develop sophisticated features via WeChat's application program interface (API)s. In computer programming, an application programming interface (API) is a set of routines, protocols, and tools for building software applications. On the WeChat Official Account Platform, a subscription account is allowed to send 1 broadcast message per day, while official accounts using developer mode can broadcast more flexibly using this API.

3.3. Open Platform

Wechat open Platform enables the synchronization between WeChat and websites. Contents on WeChat could be shared from the website or contents on website could be shared from WeChat. Furthermore, Micro-community which can be used on public account allows subscribers to interact with other subscribers and share with their social network circle.

4. Analysis of Wechat Affordances for Mobile Learning

The above-mentioned features and functions of Wechat can provide affordances of creating mobile learning favorable environment for College English learning and teaching. By Analyzing the features and functions of Wechat, we examine the Wechat affordances for mobile learning, as is given in Figure 1. First, the basic functions of Wechat allow interaction communication by using Text messaging or Voice messaging or Group chat, which can provide an environment for collaborative learning between groups and interactive communication among students or between students and teachers. Second, the Public Platform of Wechat allows subscription account owners to push content to every subscriber, which can be used to deliver course content to students' mobile phones. In addition, automatic reply function on Public Platform allows subscribers to retrieve course content. Third, Wechat Open Platform enables the synchronization between WeChat and websites. Contents on WeChat could be shared from the website or contents on website could be shared from WeChat, which allows teachers to easily share learning resources with students. As an American community college teacher noted after using Wechat in his large classroom for student interaction, "One thing that became abundantly clear as an advantage of using WeChat is that you have an instant written record of student discussions. You can't get that with live discussion. That's a pretty powerful tool for being able to gauge student learning and where students might be getting stuck on lecture content. The instructor can go back and look at the WeChat comments versus trying to recall from memory the verbal discussion" (as displayed in Fig. 3).

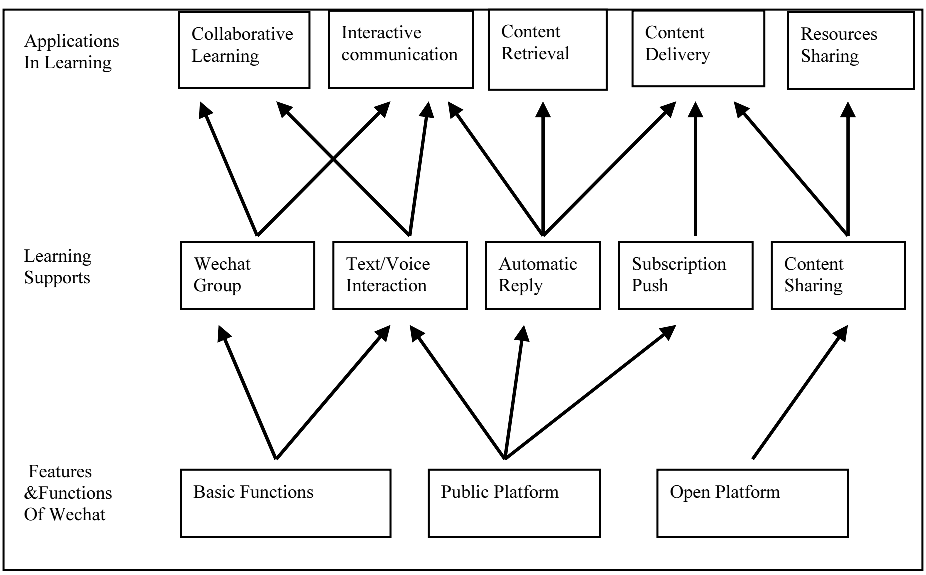

Fig 1. Wechat Affordances for Mobile Learning

Fig 2. The Public Accounts a User Subscribes on WeChat

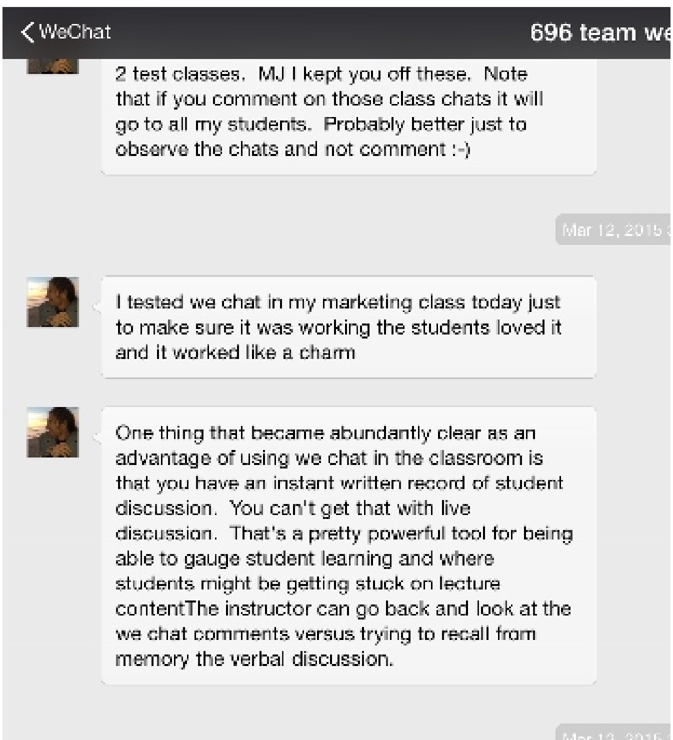

Fig. 3. An American Teacher's Use of WeChat in his Large College Classroom

5. WeLearn: A Learning Management System (Light) Based on Wechat

Taking advantage of the mobile features of Wechat, several leading e-learning companies in China (e.g., Shanghai's Longtime Inc.) developed a learning management platform called WeLearn. Below are a screenshots of a course developed by Seven-in Learn, Inc. in Shanghai, for Hospitality English, a course produced by San Diego State University with the support of Marriott Foundation. WeLearn has the following advantages over a traditional or responsive website:

- Accessibility: once users subscribe to it, they can easily access it from their Wechat account.
- Popularity: In China, almost everyone with a smart phone has the Wechat app installed. They can chat, call, video-conference, transfer files, and form personal and professional groups.
- Flexible menu and navigation: an instructor can customize the menu in WeLearn and encourage students to interact in WeChat.
- Record Tracking: WeLearn is a learning management system Light. It has the ability to track every user's learning path and progress.

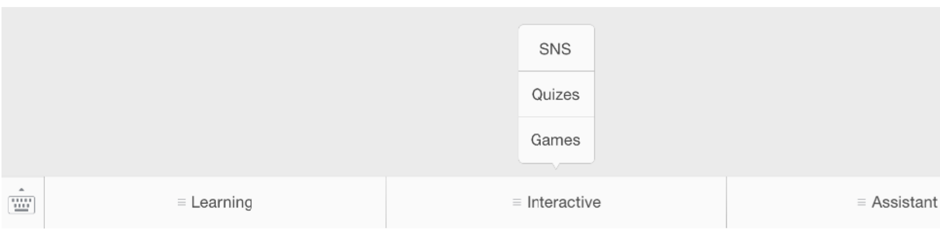

Fig 4. The Navigation Menu of Welearn

Fig 5. An Exemplary WeLearn Course Demo: teaching hospitality English for the Marriott Project

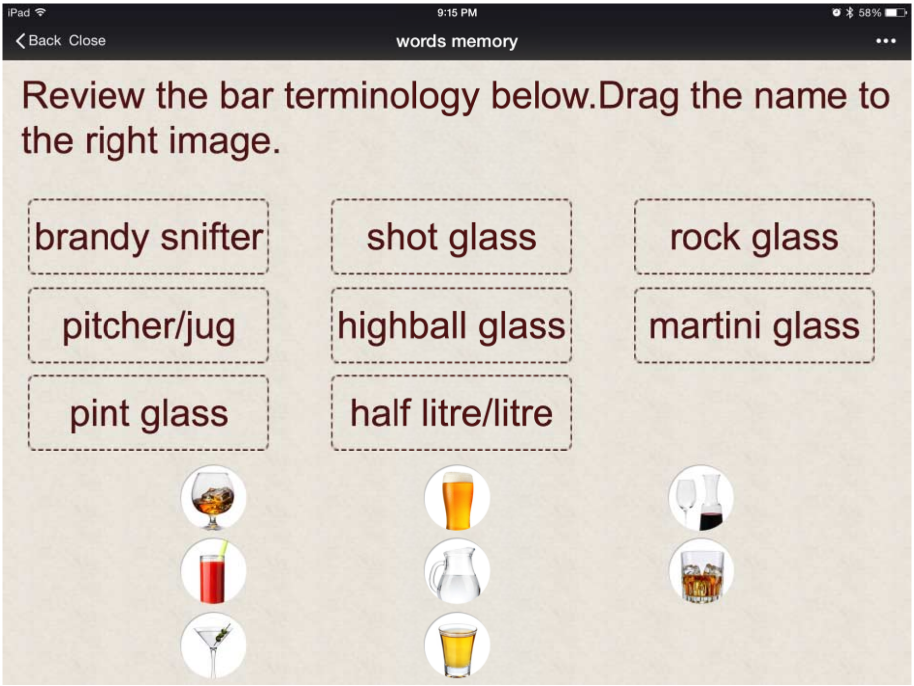

Fig 6. An Interactive Quiz in WeLearn: for Hospitality Training (CHEI)

6. A Pilot Study of Mobile Learning of College English based on Wechat

6.1. A case of Mobile application of Wechat Public Platform

WeChat public platform is a new updated functional module developed by Tencent of China. There are three basic functions which make the platform strong when they are combined as a whole: bulk messaging, automatic reply, and the two-dimensional QR code. Based on the triple functions of the WeChat public platform, we can further explain the specific case: the process of registration of an activity using this platform.

6.1.1. Background of the case

Here we assume the activity to be a seminar about *College English* hosted by a University in Wuhan. The University will host a seminar on a certain time in a certain meeting room. Every seminar will have a theme, information about the speakers, and number of participants the room can accommodate. The media department of the University will notify the students and teachers about the seminar through their WeChat public platform.

6.1.2. Building an instance application of WeChat public platform.

Now we start to build an application named *Seminar Registration* based on the public platform. After building the application, we need to import the lists of students and teachers of this University who might be interested in joining the seminar.

6.1.3. The process of registration of an activity using WeChat public platform

Next we describe the process of registering an activity using WeChat public platform on the basis of the application seminar Registration.

First, the media department submits a seminar and provides the detail information about the seminar. Then the application seminar Registration will send message about the seminar to the list of students and teachers by the function *Bulk messaging*. At the same time, a two-dimension QR code containing the information of the seminar and the registration will be published on the application and the website of the college. Then students and teachers who are willing to attend the seminar can scan the QR code with their cell phone and register in the seminar. The automatic reply function is an information exchange tool. Students and teachers can get the information about the seminar by replying corresponding word to the program and receive the details they want to know. For instance, a student can reply to the program a sentence containing the word speaker which is a kind of replying rules set by the application. Then the program will reply with the corresponding answers.

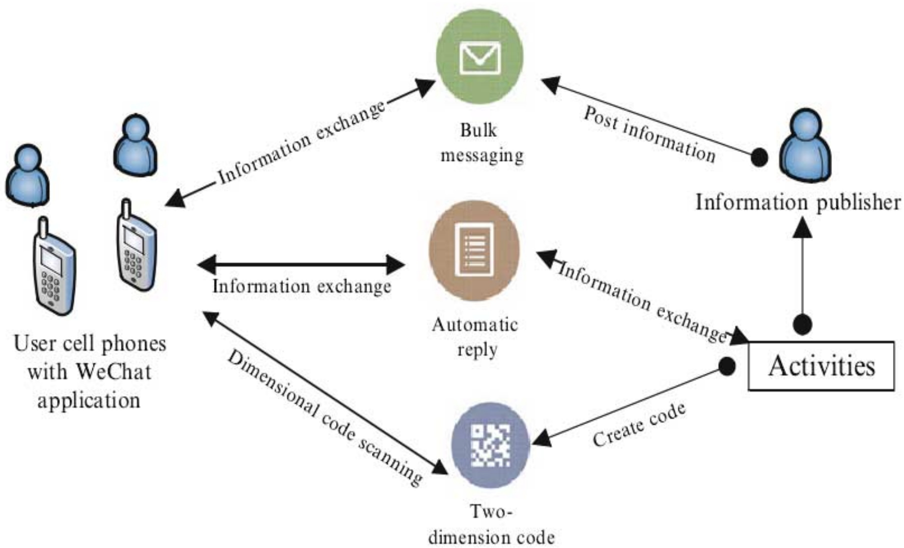

Fig 7. The Process of Registration of an Activity Based on Wechat

6.2. Content design for Wechat-based Mobile Learning Platform

The teacher can use Wechat public platform (subscription account) to broadcast to the subscribers (students) to deliver micro-content on mobile devices of the students and allows learning anytime, anyplace and any pace.

Micro-learning has great potential for learning on mobiles. Leene [9] views micro-content learning as focused, self-contained, indivisible, structured and addressable content. It integrates different forms of media in short form: text, video, audio, interactive element used as micro media in fragmented time .

Regarding many different forms of learning, micro-learning is dedicated to information retention and thus build-up of factual knowledge. Bruck suggests four basic characteristics which can serve as a starting point for designing and developing micro-learning solutions [10]:

1) Repetition of the learning content
2) Continuity in repetition activity
3) Assessment before progressing to next unit
4) Good organization of content in a manner supporting systematic search of information such as in hierarchies.

6.3. The Structure of an Innovative Teaching Model with Mobile Learning

According to College English Curriculum Requirements published in 2007, in view of the marked increase in student enrolments and the relatively limited resources, colleges and universities should reform the existing unitary teacher-centered pattern of language teaching. This model should incorporate the strengths of the current model and give play to the advantages of traditional classroom teaching while fully employing modern information technology. A new teaching model based on modern information technology including computer-based and mobile phone-based technology is needed in order to achieve student-centered, autonomous learning. The structure of an innovative teaching model of College English is shown in Figure 8:

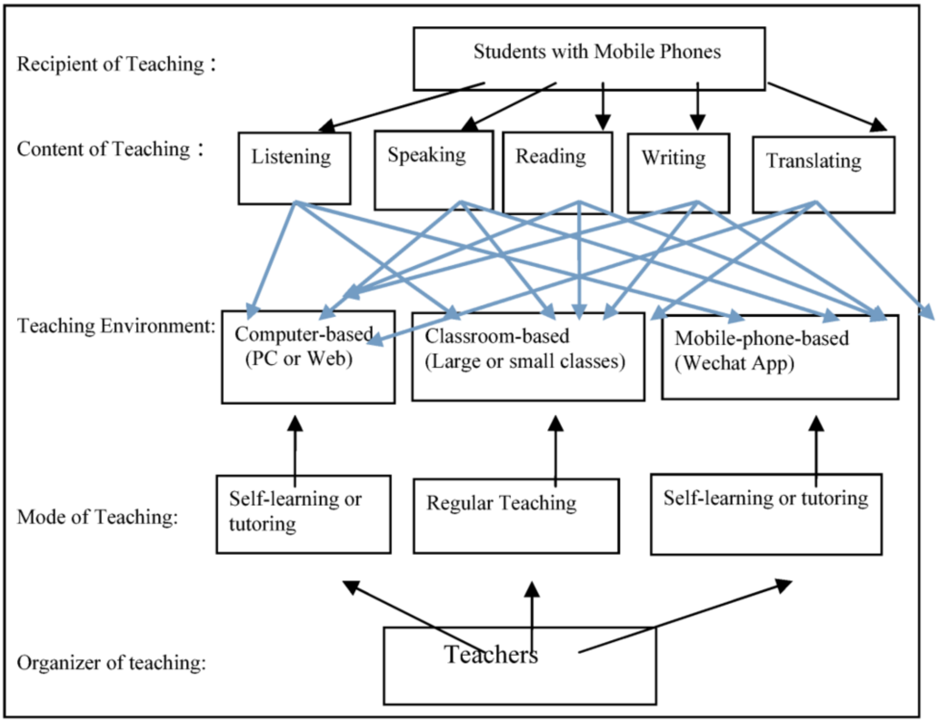

Fig 8. Structure of the New Teaching Model

The goal of the College English course is to develop students' abilities to use English in listening, speaking, writing, and translating. In this new teaching model, as the learning facilitator, before class teachers can ask students to go to study in the self-learning center of the university. After class course content can be delivered to students' mobile phones to learn or review in their free time, especially it helps them use fragmented time. In class, the teacher can give feedback to students based on their performance in both the computer labs and on their mobile phones.

Moreover, Wechat Open platform can be designed to help to track down, record and manage learning and tutoring as well as the monitoring and management of learning and tutoring. Micro-community of Wechat can be developed to achieve interactive communication between students and teachers or among students. The new teaching model with Wechat-based mobile learning can attain to a high level of interactivity, the use of multimedia, and operability.

7. Conclusions

This paper presents an in-progress pilot study of how to integrate mobile learning of College English based on the Wechat public platform with reference to content design and structure of teaching model of College English. We plan to have instructional materials and learning activities developed for the WeLearn platform and conduct systematic research. The research will address the design of the WeLearn course and how teachers and students conduct learning activities on this innovative learning management system.

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Using Science Fiction Prototyping to Decrease the Decline of Interest in STEM Topics at the High School Level

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Abstract. In order to address the lack of student interest in STEM subjects and the dwindling number of students pursuing STEM careers, the Creative Science Foundation (CSF) has developed an easy to deploy educational strategy. This strategy, effectively titled Science Fiction Prototyping, utilizes science fiction stories and material to "explore the possible implications of research and technology on humans, societies, and the world." It is also possible that these prototypes can be used to increase STEM motivation in students. The researchers will first perform a meta-analysis and literature review to determine the present outlook of STEM curriculum, student interest in STEM careers, and student enrollment in STEM careers after graduation. Other parts of the research project include a pilot study to explore the feasibility of using science fiction prototypes within a high school environment to increase student interest and attraction to STEM related careers.

Keywords. Science Fiction Prototyping, STEM, Science, Technology, Engineering, Mathematics

1. Introduction

In recent years, high school student interest in Science, Technology, Engineering, and Mathematics disciplines has declined. This study was conducted in an attempt to determine the cause of the decline and the validity of Science Fiction Prototyping as a strategy for motivating and increasing student interest in STEM topics. This is a follow-up to previous studies conducted by Professor Vic Callaghan, Director of the Creative Science Foundation and Professor Emeritus of Computer Science at Essex University in Colchester, United Kingdom, and Brian David Johnson, a futurist at Intel Corporation, whose future casting, the process of using ethnographic field studies, technology research, trend data, and Science Fiction to provide Intel with a pragmatic vision of consumers and computing, made him a pioneer in development of artificial intelligence, robotics, and Science Fiction Prototyping.

After the research team reviewed existing literature and hosted a small Science Fiction Prototyping (SFP) workshop, the research team found that while SFP can be a fun activity, SFP did not affect student's interest or motivation towards STEM disciplines. Results were limited due to time constraints and a lack of diversity in the

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samples. However, the findings highlighted appropriate methods to test the validity of SFP.

2. Impact of the Literature Review

A review of existing research reveals that the diminishing interest in Science, Technology, Engineering, and Mathematics (STEM) disciplines can be attributed to numerous environmental, educational, cultural, and societal barriers. Students are also not pushed to connect everyday technologies, like mobile phones, computers, and other innovations, to STEM disciplines. Without an understanding of how STEM disciplines influence our electronically interwoven society, students become users of technology rather than innovators.

Numerous barriers exist that impede the creative thought processes of students. The high school level of science literacy is declining in the United States, which now ranks below the world average in producing STEM graduates [7]. One study claims that the problem began with the implementation of the No Child Left Behind policy, as the policy reduced the science curriculum and the lessoned the importance of science related test scores [1].

More barriers to student interest in STEM are the student’s environments. Their socioeconomic background, race and ethnicity, gender and parents’ academic level all heavily influence interest in STEM careers [8], [9], [5]. Low socioeconomic levels prevent students from being able to tap into resources that wealthier students have readily available for learning [9]. Parents’ personal educational achievements also correlate highly with a child likeliness to be encouraged and challenged throughout their life to explore STEM topics.

Gender, race and ethnicity challenges have the greatest impact on STEM interest and take-up. This is because certain cultures have practices that discourage education. For example, minority women are less encouraged to pursue STEM topics. Both the scientific community and culture often ostracize women that pursue STEM fields [8]. Low-income communities have fewer resources available and teachers who are qualified to teach STEM subjects. Teachers in low-income communities are required to teach science and mathematics, subjects in which they are not subject matter experts [5].

Science Fiction Prototyping (SFP) is one strategy proposed as a possible solution to the lack of contemplation and motivation shown by students in regards to pursuing STEM careers [3], [4]. SFP is a learning activity where fact and imagination are coupled to create a story of how an innovation put to use in a future setting would affect the people of that time socially and economically [3], [4]. The student is encouraged to imagine how the people would interact with the new technology, what problems would the technology solve, and what new problems could it [3], [4].

The biggest idea behind SFP is that students should be able to critically think about the interaction between society and emerging technologies. Emphasis should be placed on the use of science to provide testing for possible scenarios [3], [4], [6].

3. Contextual Factors

There are several factors that impacted the design and implementation of this study, the biggest being time. When the research team progressed to the point of data collection, local area schools were on spring break, so connecting with teachers and convincing them to allow researchers to affect their instructional time proved a challenge. It would have been preferable to have the pre-survey administered days prior to the prototype presentation. Due to time constrains our entire population was a small sample size with little diversity.

4. Methodology

4.1. Research Design

The research team developed a pre and post survey to analyze the students' experience, interest, and motivation towards STEM topics. The pre-survey asked questions that categorized students previous experience with and current interest in STEM. It also asked students to rate their satisfaction and enjoyment of STEM activities and clubs. The primary goal of the pre-survey was to understand current inhibitions towards STEM and develop a baseline that could be used in comparison with the post survey. After the pre survey was distributed, a member of the research team led an in-class presentation and activity. Immediately after the in-class presentation and activity, the post survey was distributed. The post survey asked similarly worded questions to the pre survey in order to easily quantify a decrease or increase in interest and motivation of STEM. Compared to the pre survey, the post survey had more Liket questions that asked students to rate their satisfaction, interest, and motivation towards STEM. The primary goal of the post survey was to expand upon the baseline set through the pre survey to gauge any change after the STEM activity. The students were asked to write their first name and the date on each page of the pre and post surveys so the research team would be able to compare the results.

4.2. Participants

Our audience was comprised of two high school classrooms of Earth Science, one of 28 students, and the other of 26 students, giving a total of 54. The frequency of boys and girl was basically even, since as the class sampled had a total of 28 boys and 26 girls. All the students come from similar socioeconomic backgrounds, ranging from low to middle class, most of them, not having much experience with STEM classes, except for their shared Earth Science class, and a few varied mathematics classes such as Algebra and Trigonometry. Something that was different was the age range, the classes mostly comprised of 14 year olds (64.8%) and 15 year olds (35.2%), though there is no evidence yet of this being significant in the study.

A pre-survey was administered on paper at the start of each class session directly after a very brief introduction of the researcher and purpose. The teacher helped facilitate distribution and collection of the survey, as well as respond to student questions about how to address survey questions. Students were asked to mark their pre-surveys with a small icon, drawing, or other mark that would also be added to the post-survey. This strategy allowed for matching of pre and post-surveys without identifying individual students, and proved to be very effective.

4.3. Instruments

To that end, a workshop was put together that:

- Introduced Brian David Johnson and Vic Callaghan, and how they use prototypes
- Introduced prototype concept by providing an overview of prototype examples:
  - Presented premise of Nebulous Mechanisms.
  - Held a class discussion about Jurassic Park, the science it presented, and how the story explored the possible impact through the narrative.
  - Showed a video prototype (A Day In the Life of Glass) to deepen understanding.
- Showed examples of other ways prototypes are used.
- Had students engage in a class brainstorm exploring a prototype idea.
- Navigated to the Creative Science Foundation website and described the T-Fiction process and the competition opportunities.
- Got students into groups to write their own T-Fiction samples and share the resulting stories with the class.

The post-survey was administered and collected directly after the session during the same class period.

4.4. Data Collection and Analysis

After the pre and post surveys were answered and collected, the quantitative information from questions 1 through 7 on the pre survey, and questions 4 to 7, where documented in an Excel sheet for further comparison. With the aid of the attachment application Analyse-it, the research team was able to analyze the data obtained, and make more sense of the mindset of the students surveyed during the activity.

5. Findings

As previously stated in the instruments section, the research team created two surveys. The first survey, a pre survey, was distributed prior to the Science Fiction Prototyping (SFP) activity, while the second survey, a post survey, was distributed after the SFP activity to effectiveness on SFP increasing the audience's interest in STEM.

Of the pre and post surveys, nine questions were quantitative and their means and standard deviations are displayed in this table where the students were asked to rate each category from 1-6 (whenever the standard deviation is bigger than 1, it means the students' opinion varied a great deal).

Table 1. Descriptive Analysis of Survey Responses

Survey Question for pre and post survey	Mean Pre Survey	Mean Post Survey	Standard Deviation Pre Survey	Standard Deviation Post Survey
Current interest in required STEM classes	3.7	1.1	4.0	0.9
Current interest in required STEM electives	3.7	1.3	4.3	1.1
Current interest in STEM Clubs	3.6	1.5	4.1	1.4
Future interest in Required STEM classes	4.0	1.0	4.2	0.9
Future interest in STEM Electives	3.8	1.4	4.4	1.0
Future interest in STEM Clubs	3.8	1.4	4.1	1.3
Enjoyment in Current Required STEM classes	3.9	1.1	4.0	0.9
Enjoyment in Current STEM electives	4.0	1.4	4.1	1.2
Enjoyment in Current STEM Clubs	4.0	1.6	4.1	1.3

$N = 54$

From the pre to the post survey, most of the means increased, albeit very slightly, when in most cases at the pre survey the standard deviation was more than 1 (except for Future interest in Required STEM classes), the research team observed a slight decline in the post survey standard deviation, showing the opinion of the students varied less once they went through the activity.

Aside from observing the variations of opinion between students (for which the team has yet to find a correlation for their way of thinking about STEM previous to the activity), the main objective was to measure student's reactions towards STEM once the Science Fiction Prototype was administered. T tests (with α=0.05) were conducted to compare the mean rating differences on the above survey questions. If there was such a p-value less than α=0.05, then there is evidence of change in STEM attitudes after the activity.

Table 2. Paired T test Results of the Nine Quantitative Responses

Survey Question for pre and post survey	p-values for pre and post survey	T value for pre and post survey	DF (Degree of Freedom) for pre and post survey
Current interest in Required STEM classes	0.0410	2.09	53
Current interest in STEM Electives	0.0010	3.50	53
Current interest in STEM Clubs	0.0092	2.70	53
Future interest in Required STEM classes	0.1919	1.32	53
Future interest in STEM Electives	0.0005	3.71	53
Future interest in STEM	0.0945	1.70	53

Clubs			
Enjoyment in Current Required STEM classes	0.3316	0.98	53
Enjoyment in Current STEM electives	0.6162	0.50	53
Enjoyment in Current STEM Clubs	0.2827	1.09	53

As Table 2 shows, the most significant change occurred in the current interest in STEM questions (0.0010, in Green), which shows that the activity was a fun and motivating option for STEM education at the high school level. Although, it was not motivating enough for future endeavors in Required STEM classes and Clubs, it did seem to inspire the students to look for fun STEM Electives as a future option (0.0005, in Red). Still their level of enjoyment of STEM in general did not seem to increase, quite the opposite, it seems the students are still predisposed to loath STEM education.

It is evident through the student's disappointment and lack of interest in pursuing future STEM classes that the activity did not last long enough. The research team can surmise that Science Fiction Prototyping is a good way to inspire high school students to enjoy STEM classes if applied from early on and for longer periods than the 40 minutes allotted for our test experiment.

Although this study does not delve too deeply on the idiosyncrasies of SFP itself, it gives a small glimpse of the audience and the obstacles it will run against in the hopes of motivating students to pursue STEM through SFP, and can set the groundwork for further studies. Since this is the first time SFP has been tested at the high school level, the research team considers the results to be as expected, since it's accepted that SFP alone will not eradicate STEM antipathy, yet it could be a useful tool to shake the monotony of lectures and standardized testing.

Even though, not precisely quantitative, pre survey questions 8 through 11, also gave a glimpse of what the mindset of the students was before the activity. Most of the students did not enjoy STEM, or just went along because they either liked their teacher, or their friends were in the class. They tended to complain that the class was either too difficult or boring or even had a hard time finding relevance to the subject. After all this being asked if they had plans for college, came as no surprise that a great deal of them were not sure or not decided to continue furthering their education. Moreover, if a major in college was suggested, it usually was not a STEM-related career.

After the activity however, the post survey proved that the students enjoyed the activity, felt at the time motivated by it, and regretted the lack of time to develop their own prototypes.

6. Conclusion

It will be important in future research to include the following:

6.1. Work with teachers prior to engaging with the students.

Engaging with the teachers in order to help them fully understand the goals and process of the research will ensure that the class is prepped and ready for researchers to come in and get started without having to lay significant groundwork. It also may encourage teachers to grant researchers more class time for investigation and study. Teachers know and understand their students, so it will behoove researchers to enlist their support, as they can propose suggestions or changes to the planned methodology that will elicit more effective or valuable data. For example, after the first presentation, the teacher involved in this study provided context and information on what the students needed that greatly improved student response in the second presentation. Although all of the students in this project were in ninth grade, future student samples should span the grade levels. Teacher input would be necessary to ensure grade-level appropriateness of presentation content.

6.2. Perform focus groups for data collection.

When given the opportunity to speak freely about their opinions toward STEM, the student participants expressed their feelings more comprehensively than the survey would allow. When students struggled to articulate an idea, others would chime in to help complete thoughts.

It should be noted that when the students were verbally questioned about engaging in the prototyping activity, the response was overwhelmingly positive. They said they wished they had more time to come up with prototype ideas and time to develop the stories. When asked by the facilitator if they had a choice to take science fiction prototyping as a class, the students gave a resounding, “Yes!” The student participants also spoke about how they would be more apt to like STEM classes if they were to incorporate prototyping, because it would make the class content more relevant to them.

6.3. Utilize current and emerging technologies to engage the learner in the prototyping methodology.

As the study suggests, future iterations of Science Fiction Prototyping (SFP) workshops could be greatly improved by utilizing current and emerging intelligent environment technologies. By utilizing intelligent technologies students would be more engaged with SFP activities and methodology. Activities promoted by the SFP methodology, including T-fiction where students write short stories small enough to fit within a series of tweets (called T-fiction), could be enhanced through intelligent uses of mobile devices. Mobile devices would allow students to easily share their T-fiction stories with other students locally and globally. Mobile devices would also allow students to participate in global contests on the Creative Science Foundation’s (CSF) website.

Two additional intelligent technologies that could enhance Science Fiction Prototyping (SFP) workshops are augmented reality and virtual reality. With rapid prototyping models and easy to use software, students could design, build, and share SFP prototypes with other students on a local and global scale. With augmented technology, students could augment everyday objects with videos, pictures, text, animations, and web links. Virtual reality would allow students to become completely immersed in different worlds.

6.4. Future implications and significance of the findings.

The findings show that SFP could be a good activity to get students interested in STEM, perhaps not long term yet; however it is a good instrument to use against the boredom acquired in the everyday lecture classroom. The research team surmises that a longer

SFP activity, that goes on for days, instead of one hour, would have a higher impact on the students towards STEM, and it should be the next step in research to validate the need for SFP in high school classes.

Since this was the first time SFP has been introduced to the high school level, the research team did not anticipate a significant change in the students' mindset about STEM; however, the team was pleasantly surprised to see the students asking for more, even if they were not entirely convinced of pursuing a STEM class, much less a career, after the activity. The team predicts, that the continuation and better planning of SFP added on a more often basis to STEM high school classes will definitely have an impact on more students liking STEM and changing their schemas. The research team thinks that a reason for the students to reject STEM is due in great part to having developed early in life a predisposition to hate STEM topics. One class will not change their minds. Moreover, repetitive fun activities, such as SFP, will help students change their previous schemas, and create a new love for STEM.

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Evaluation of Curriculum Developed From a NSF-Supported Teacher Workshop

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Abstract. This project evaluates the educational component in support of a U.S. National Science Foundation (NSF) grant to study the system of payments in the Fanjingshan National Nature Reserve in China, the habitat of the endangered Guizhou golden monkey.

Keywords. Innovative Practice in Mobile Learning, New Pedagogy for the Digital Age, Environmental Education, Project-Based Learning, Teacher Professional Development

1. Introduction

The U.S. National Science Foundation (NSF) awarded a large four-year grant to San Diego State University (SDSU), for studying the human-environment interactions in the Fanjingshan National Nature Reserve in China, the habitat of the endangered Guizhou golden monkey. The Impact of Ecosystem Service Payments in Coupled Natural and Human Systems (NSF-CNH) grant is led by Dr. Li An from the Department of Geography and includes an educational component, with objectives to creatively engage K-12 students in the United States and China in learning activities related to the project, to mentor the teachers and help them develop new science and Geographic information system (GIS) curriculum content. As an initial step, the 2013 Summer workshop was held in June for high school teachers in San Diego. Eight school teachers representing various educational disciplines, Math, Social Science, GIS Science, and Earth Science, participated in this workshop and created innovative curricula to engage their students in mobile and project-based learning. The objectives of the workshop were: to have teachers develop instructional activities, and to implement these activities in their classes and improve students' knowledge and awareness of the environment.

This paper describes the standards and methodology used to evaluate this educational component in support of the larger grant; specifically the effectiveness of the summer 2013 Workshop in meeting the objectives, by reviewing the instructional content developed and implemented and surveying the teachers who participated in these activities.

2. Impact of the Literature Review

In the literature review, we sought to understand best practices in effective teacher professional development and the best strategies to assess and evaluate those professional development activities. We also sought to understand the best practices of good environmental education, the use of mobile learning activities in project-based learning and GIS education. The curricula developed by these teachers would consist of elements of all these disciplines.

3. Professional Development Activities

Fishman and his colleagues present a model for teacher learning that describes several assessment strategies intended to assess teacher knowledge, beliefs, and attitudes that lead to the acquisition of new skills, new concepts, and new processes related to the work of teaching [1]. The model uses an iterative approach that includes the design and implementation of professional development (PD) activities, changes in teacher's knowledge, beliefs, and attitudes that result in enactment in the classroom and evidence of student performance improvement.

Johnson and Fargo report a positive impact on student learning increased after teacher participation in a Transformative Professional Development (TPD) program [2]. The TPD program included a whole school professional development activities, consisting of a two-week summer session institute for teachers, building relationships between teachers and their colleagues, teachers and students, and teachers, and university faculty, and creation of positive school and classroom climate and high expectations.

In their article titled *What Makes Professional Development Effective? Strategies That Foster Curriculum Implementation*, the authors summarize the best practices in teacher professional development as well as strategies to maximize effectiveness [3]. Of note to our study, the authors stated that teachers need professional development that is interactive with their teaching practice, and of longer duration and time span. This allows multiple cycles of presentation and assimilation of knowledge and is more likely to contain the kinds of learning opportunities necessary for teachers to integrate new knowledge into practice. The study recognize the importance of teach collaboration, and the importance of teachers' having meaningful, and ongoing professional development experiences. The teacher's ability to localize or tailor its implementation to local circumstances is a significant predictor of the extent to which teachers implemented what they learned. Lastly, equipment and technology support also have significant influences on new program implementation.

When taken together, these studies describe the important components to effective teacher professional development that will help guide the analysis and formative evaluation of the overall implementation of the 2013 NSF-CNH Summer workshop. The elements of on-going support between teachers and their colleagues and teachers and university faculty could be applied to the continuing educational activities under the grant.

4. Evaluating Content

As discussed previously, one of the desired outcomes of the workshop was for the teachers to develop interdisciplinary content for their classes based on material presented about the NSF-CNH project, some with a focus on the endangered golden monkeys. This includes Environmental Education; Project Based Learning and GIS education. We reviewed previous work to identify the best practices in these disciplines, which are summarized below:

4.1. Environmental Education

Effective environmental education raises awareness, increases knowledge, and affects attitudes, while acquiring the skills for identifying and solving environmental problems, both locally and globally. These foundational concepts were first identified in the United Nations Tiblisi Declaration [4].

Athman and Monroe's 2001 paper, *the Elements of Effective Environmental Education Programs*, describes the need for effective environmental education to be relevant to the learner, involve the stakeholders, and be accurate and balanced, with multiple perspectives and interdisciplinary aspects. Effective environmental education is instructionally sound, incorporates collaboration and problem-based hands-on examples and includes both formative and summative evaluations [5].

4.2. Project Based Learning

Project Based Learning (PBL) is a learner-centered approach that encourages students to conduct research, integrate theory and practice while applying appropriate inquiry skills to construct solutions [6]. PBL should also be centered on deductive reasoning and synthesis of multiple domains (interdisciplinary) approach. Quality PBL instruction requires students to think critically, analyze and solve complex and real world problems using appropriate sources. With the teacher as a facilitator, PBL requires learners to be self-directed and work cooperatively and demonstrate effective communication using content knowledge and intellectual skills to advance learning. The problems are open-ended and complex, allowing for free inquiry. The learning incorporates self and peer assessment, and regular formative assessment of content knowledge and procedural ability.

4.3. Geographic Information Systems (GIS)

The use of GIS applications, such as Google Earth, supports students' ability to apply deductive logic which will promote students' analytical skills. The works of Patterson and Semple evaluate both best practices and challenges of this type of curriculum [7][8]. Time is the major barrier in developing the teachers' GIS skills, as most teachers feel that additional time and practice is necessary to fully achieve a proficiency level in which they were comfortable using the program. The other major barrier is technology constraints, which are decreasing each year as computer and internet access improve. Both can be addressed by increasing the length of teacher professional development and the on-going support through continued and recurring opportunities to advance knowledge.

Collectively, these works provide the standard against which the environmental, PBL and GIS curriculum content can be assessed.

4.4. Contextual Factors

The contextual factors that guided our study were well established as part of the larger NSF-CNH project. Due to the ongoing nature of the project this study was aimed at evaluating the past workshop and ongoing participant implementation while striving to establish best practices and recommendations for future workshops. While we had complete access to the project materials we did find the access and completeness of the teachers' curriculum materials lacking. In addition to curriculum development and implementation deficits by the majority of the participants we also had a lack of feedback from the survey sent to the teachers for the second half of our study.

At the time of evaluation, the participants' curriculum materials were in various stages of development and implementation. A major contextual barrier for the completion and implementation of curriculum was that the teachers have a full instruction load, with many time demands and a rigid schedule set by the school year and testing schedules. While the materials for the content analysis were severely limited based on the participants' fulfillment of curriculum development, we did have access to all of the materials they created and we also receive excellent materials from some of the participant. There was one contextual factor highlighted by a participant that created a barrier for the further development and use of their curriculum. They noted challenges related to the ability to obtain real GIS datasets from the NSF project.

The contextual factors for the initial content analysis were primarily limited content to analyze, the discrepancy in completeness and implementation of content as well as the challenges of evaluating disparate sources. For the second part of the study we designed a short survey for the participants to give feedback to help guide our overall evaluation and to create recommendations for this years' upcoming workshop. We only had time to administer one survey over the course of this study before analyzing the data and drawing conclusions. The survey response was somewhat limited, with only three surveys returned out of eight participants, with a response rate of 37.5 percent. The three surveys that were completed were very valuable and did give specific information that has helped us evaluate last years' workshop and create recommendations for successive workshops. Participants expressed an interest in more time for collaboration. Considering that the participants taught different subjects and had different curriculum goals it not possible to give universal recommendations due to limited feedback from many of the participants. However through the evaluation process and research into best practices for this project, the continued educational component and its effectiveness and impact is expected to improve.

Among the surveys returned, participants expressed an interest in more time for collaboration. One teacher expressed frustration in obtaining real data from the project that could be utilized in the classes. This is mainly due to Institutional Review Board constraints and the early stage of the project. As the study continues, this may be an area for future emphasis and collaboration among the project partners.

4.5. Methodology

The methodology used in our survey can be broken into the two parts of our study, content analysis and survey. The focus and approach to our content analysis was heavily guided by the best practices established through our literature review. The survey was designed to help gather specific information that would clarify issues with last years' workshop and generate recommendations for upcoming workshops in the remaining years of the grant.

The content analysis used an inductive comparative approach to help describe the relationship between the 2013 teacher workshop content and the participants' (K-12 teachers) curriculum. We analyzed the materials presented at the 2013 teacher workshop and the curriculum created by the K-12 teacher participants. The content analysis broke down the content by subject matter and categorized the curriculum into the areas of Environmental Education, Project Based Learning, and GIS Education. Once the curriculum content was broken down, evaluated, and categorized we then looked at the source (from the presentations at the workshop) of specific curricular content. We created a comprehensive chart that shows the direct influence of the workshop presentations on the curriculum created (see Figure 1.)

The second part of the study involved a short survey to collect participant feedback to help with our evaluation and recommendations. We created the questions to help clarify the participants' evaluations of the workshop. The survey was designed to get qualitative feedback more than data.

5. Findings

The findings from our evaluation are composed of two distinct parts. The first part being the evaluation of the workshop, its content and the relationship and impact it had on the development and implementation of curriculum by the participants. The second part of our findings focus on the best practices and recommendations that we gathered and created based on our overall study, the literature review, and the participant survey.

The overall findings from our analysis of the workshop demonstrated that while there was limited transfer and follow through from the participants as a group, there were individuals that did create some quality and even exemplary curriculum.

The findings for the workshop evaluation point to the fact that within the limited participation and completion of curricular products by the participants there was strong and desirable influence by the workshop presentations. Some of the presentations were clearly more relevant to the group as a whole such as the presentation on the far right by Shuang Yang, one of the doctoral students supported by this grant. The content from this presentation showed up in most of the participants' curriculum, likely because it presented baseline facts and information along with many great pictures. The two presentations that covered GIS and remote sensing did not see as much osmosis into the participants' curriculum, likely because only a couple of the participants work with this type of technology. A clear recommendation that arises out of this analysis is the need for the workshop presentations and presenters to make their content as relevant as possible to the diverse audience.

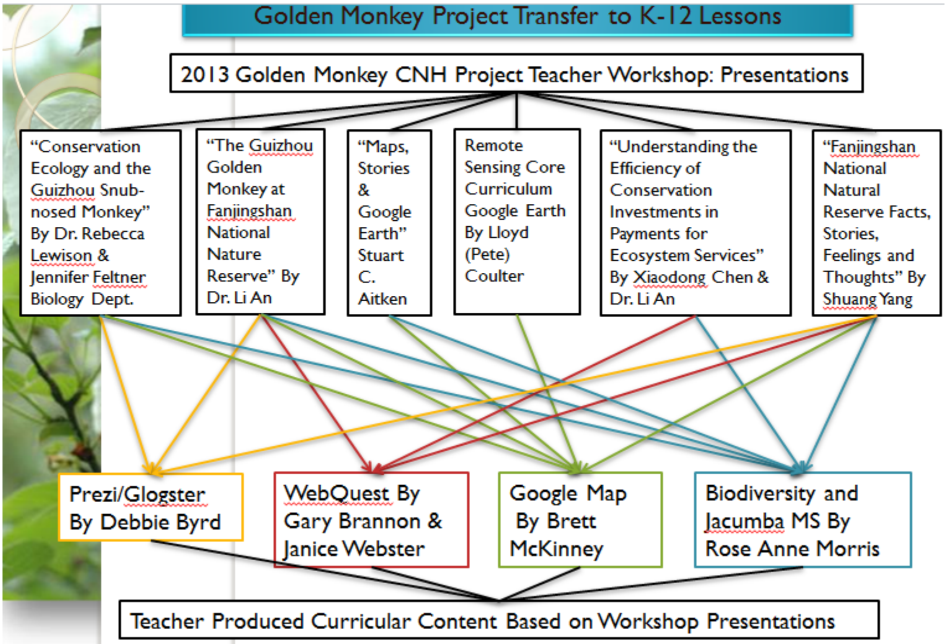

Figure 1. Workshop Influence on Curriculum Created.

The survey and other assorted feedback (primarily email) we received from the participants along with our understanding of best practices for professional development from our literature review led to the following findings.

- Follow up such as what our study team did with the teachers needed to be done in the fall, winter and earlier in the spring in order to encourage and support teacher completion of curriculum with enough time to implement before testing and end of year activities.
- Participants have noted challenges related to the ability to obtain GIS datasets from the NSF project. As a participant noted about the availability of GIS data "We did not have a lot of info to go off of from the summer. It was, I recall, mostly private and protected, not for outside use." (Appendix A, Q5P3) Presenting the data in a user friendly and clear manner (graphs, charts, and datasets) could support the participants' inclusion of more direct project research into their curriculum.
- Collaboration work time was a key component highlighted in the best practices from our literature review and was a point noted by a participant in their survey response. "Time to discuss and apply discussion to assignment. Brainstorm ideas for application of lessons in new ways." (Appendix A, Q5P1)

The overall findings of our study highlight that while there was success of transfer from the workshop to the curriculum development, there were some deficits in participation and overall completion of participant products. This shortcoming may be attributed to simple time constraints, lack of collaboration and follow up support as well as lack of direction from the participants themselves. Despite some of the shortcomings of the workshops, impact clearly shows in the diversity and quality of curricula created, and meaningful educational curriculum can be developed and implemented based on the Golden Monkey project research. The value and uniqueness of the Golden Monkey project as an educational tool is highlighted by this quote from a participant about their students. The students "enjoyed the out of textbook experience, going into the field to collect data, and thinking about how China's activities compared to their own." (Appendix A, Q3P2). Overall our findings support the continuation of the teacher workshops with some minor modifications and supports to improve the transfer and effectiveness for both the project team and the teacher participants.

6. Conclusions

Following the Golden Monkey Summer 2013 Workshop, several new and engaging lesson plans were developed in a variety of formats. These lesson plans varied greatly in length, depth, and degree of implementation. The content developed generally reflects many of the best practices of environmental, PBL and GIS education. Some of the teachers were able to carry out the lesson plans in their classes. There needs to be on-going collaboration or discussion amongst the teacher participants during the implementation phase. While all teachers joined the Schoology collaboration website, ongoing activity and postings are needed to help them generate ideas. One of the opportunities recognized during this formative evaluation is the benefits of ongoing dialogue and collaboration between the teacher workshop participants and also with university faculty. One of the recommendations for future years is to add periodic opportunities for ongoing collaboration throughout the year, either together with participating teachers, with SDSU staff, or potentially with educators in China. Given the teachers' desire to obtain real data from the NSF-CNH project that could be utilized in the classes, as the study continues, this may be an area for future emphasis and collaboration among the project partners. At the time of the study, the majority of the teachers have not yet implemented the curriculum that was developed. The lesson that was implemented was well received by the students. This lesson plan utilized many best practices of PBL and project based learning, however, it did not include a GIS component. The lesson plan meets the goals and objectives of the workshop.

During the 2014 year two additional workshops were held and the recommendations and best practices that were put forward in the above report were implemented. Initial results are positive as participation and follow through have exceeded the 2013 workshops. A further evaluation of the 2014 year workshops is needed to demonstrate the full value and success of the educational component of the Golden Monkey project.

Acknowledgement

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Appendix A: Participant Survey Administered

Q1: Which day or days in the week of May 12-16 would be best for attending a Golden Monkey project meeting and presentations?

P1: Monday, Wednesday
P2: Monday, Friday
P3: Monday-Thursday
Q2: How did you implement the curriculum material obtained from the workshop in your classroom?

P1: Did not have time in the curriculum plan for Biology, only had one semester course this year. Content did not apply to other course assignments.

P2: Jacumba Middle School 6th and 7th grade students spent the first three months of the school year looking at biodiversity and the content of their textbook lessons. We examined the lake next to our school and used it as a model to understand how the Fanjingshan Mountain in Guizhou Province study helps scientists to understand the goods and services of biodiversity for various ecosystems. We also completed the Biodiversity unit provided by the Environmental Education Initiative (EEI) of California. You can find that here: http://www.californiaeei.org/. We collected and dried the plants of the lake area for classroom display and a display at the local public library. We trained at the San Diego Natural History Museum to donate to their plant collection. We adopted a section of their San Diego County grid for the Plant Atlas Project for the museum, http://www.sdnhm.org/science/botany/projects/plant-atlas/. We studied invasive plants and volunteered to help with their removal. We used this http://whatsinvasive.org/.
We studied the endangered species that visit the lake using http://jacumbabirding.com/. We looked at habitat loss and degradation as we collected data around the lake. We did some Project Learning Tree activities and created poems about adopted trees, https://www.plt.org/environmental-curriculum-elementary-middle. We collected trash and put it in the school dumpster. Soon we will begin our Spring curriculum on Biodiversity and begin our spring collection of plants while we do what we can to clean up the lake area and free it of invasive species, http://archive.fossweb.com/modulesMS/DiversityofLife/index.html. We will also use this http://www.ck12.org/book/CK-12-Understanding-Biodiversity/. My students will be creating an eBook to tell the story of their study in biodiversity this year. We created newscasts and connected global issues, such as the loss of biodiversity, to genetically modified organisms. We focused on human activities and predicted what consequences we might see in the next few years if human activity does not change.

P3: I was not able to do my Google Maps project because there is no easy way (from what I have learned yet) to have students copy my template and create a new map without altering the original template. Once I learn how to do this, kids will be able to create their own maps. Instead, I lectured about the needs of the villagers vs the needs of the preserve, had students take notes, and asked them to write a paragraph explaining which side has more deserving (for lack of a better word) of the resources. It was a very basic covering of the topics as that is all the information I had access to. Kids basically got notes from my notes, a copy of a copy, from the info provided over summer.

Q3: How well was the content received by the students?

P1:
P2: They enjoyed the "out of textbook" experience, going into the field to collect data, and thinking about how China's activities compared to their own.
P3: I can't say they were super excited about it. Students don't come in to class with a great deal of background knowledge about China. I think to them it was just another assignment. To be successful, it needs to be made relevant or comparable to their daily lives.

Q4: In your opinion, what was the impact of the lesson on student learning?

P1:
P2: They got a feel for doing real science, for learning about people in another country, and thinking globally.
P3: Limited, as the information provided was very limited.

Q5: What would you like to see for this year's upcoming workshop?

P1: Time to discuss and apply discussion to assignment. Brainstorm ideas for application of lessons in new ways. Actual mapping data and ability to implement into lesson to incorporate technology. More organized less rushed workshops.
P2: I look forward to getting ideas from what others have done. Is there another year with the grant for us as teachers too?
P3: Data. Something that we can use and is appropriate for 9th graders. We did not have a lot of info to go off of from the summer. It was, I recall, mostly private and protected, not for outside use.

Q6: What additional support would help you in further developing curriculum from the workshop?

P1: Time to work with collaborators
P2: I would like to know what data has been collected and think about how I could "bring that home" to my school and then do comparative data collection.
P3: Data.

Q7: What was the biggest barrier to implementing curriculum from the workshop?

P1: Time in curriculum, change of teaching assignments. Focus of mapping data was lacking.
P2: None, since I do what I want in my classroom! I did pay the FOSS kit out of my own pocket though (approx. $2,000.00).
P3: I think my colleagues would agree with me that data, or basic usable information was lacking, as was a clear understanding of our role and expectations of us in this process. I am still not sure of our role. Is it just to create a lesson to be implemented in class? Is it for kids to do research?

Q8: Would you be interested in discussing more in depth your survey responses and experience at the workshop? Please enter contact info in comment box.

P1: Yes
P2: Yes
P3:

Q9: Please write any questions or comments you may have in addition to what you have written above. Thank you very much for your time and consideration.

P1:
P2: As it turns out, the week you have chosen is the week that my 8th graders will be taking a CST exam. I will find out what two days that is when I return on Monday. The tests are in the morning, and if you are meeting in the afternoon, as we did last year, then any day is probably fine. I believe my principal would even let me miss a test day since the test is not counting.
P3:

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Proceedings of the 1st Immersive Learning Research Network Conference (iLRN'15)

Editors

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Workshop Proceedings of the 11th International Conference on Intelligent Environments
D. Preuveneers (Ed.)

doi:10.3233/978-1-61499-530-2-211

Introduction to the Proceedings of iLRN'15

Effective immersive learning experiences are created within multiple media using myriad techniques and employing a wealth of knowledge that spans many disciplines. This includes but is not limited to computer science, user experience and media design, the learning sciences, architecture, game development, artificial intelligence, biology, medicine, and the thousands of disciplinary and occupational content areas wherein immersive learning and training may be relevant.

The vision of the immersive Learning Research Network (iLRN) is to develop a comprehensive research and outreach agenda that encompasses the breadth and scope of learning potentialities, affordances and challenges of immersive learning environments. To achieve this, the iLRN mission is to invite and organize scientists, practitioners, organizations, and innovators across the disciplines to explore, describe, and apply the optimal use of immersive worlds and environments for educational purposes. Conference, meetings, and virtual symposia aim to build capacity to explain and demonstrate how these immersive learning environments best work using a variety of rigorous, systematic, and meaningful research methods and outreach strategies.

The objective of the iLRN' 15 is to bring together researchers, educators, practitioners, decision makers, and industry on a global scale. iLRN' 15 spans the topic range from innovative research, technologies and tools to successful services and products of immersive environments to foster learning, training, and other activities in motivational and engaging ways. The objective is to uncover and discuss emerging trends and technologies, sound research and best practices, successful products and services within an international and interdisciplinary community. This includes but not limits its focus to virtual and augmented worlds, learning and motivational games, educational simulations, mixed/augmented reality, and related learning and teaching tools, techniques, technologies, and standards.

iLRN' 15 attracted 28 full paper submissions from authors from 13 countries. These papers were carefully reviewed and finally 21 papers have been accepted for presentation. The papers are organized in the following four topic stream: iLRN main stream; a focused stream on wearable-technology enhanced learning (WELL); a focused stream on self-regulation and personalization in immersive learning environments (SPILE); a focused stream on cognitive serious gaming (CSG).

The iLRN organizers gratefully thank the Program Committee, the Special Track Organizers, and attendees for their participation and interesting discussions.

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gPhysics – Using Google Glass as Experimental Tool for Wearable-Technology Enhanced Learning in Physics

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Abstract. In this paper we argue that to be viable outside specialized domains (e.g., industrial maintenance) HMDs must be seen as part of a broader concept we refer to as Head-Centered, Context-Aware Computing. Therefore we present a fully functional application prototype gPhysics app which is based on the Google Glass platform and designed to perform an educational physical experiment in the area of acoustics. The initial application is intended for students whose task is to find the relationship between the frequency of the sound generated by hitting a glass of water and the amount of water in the glass. With this experiment, we discuss the possibilities for sensing and interaction in the head/face area. The method described here takes previous research into new directions with the specific features provided by Google Glass. We present a concrete example of our research towards a vision of head-centered computing by discussing a Google Glass app for supporting experiments in physics teacher education training and in high-school physics classes. In a first study discussed in this paper, we focus on the implementation of Google Glass as an experimental tool in undergraduate regular physics teacher education courses. Based on the theoretical framework of the Cognitive Theory of Multimedia Learning (CTML; Mayer, 2005) and the Cognitive Load Theory (CLT; Chandler & Sweller, 1991), we study the variables curiosity and cognitive load in an experimental intervention-control-group design using the nonparametric Mann-Whitney test for independent random samples. The findings indicate that curiosity is indeed affected by the app and device use, while the cognitive load does not differ significantly between the two groups.

Keywords. HMD, Google Glass, Wearable-technology enhanced learning, Physics Education

1. Introduction

While wireless communication and mobile technologies provide opportunities for new interaction approaches, active wearable computing in general (Lukowicz et al., 2006; Ward et al., 2007) as well as mobile and ubiquitous learning in particular (Hwang et al., 2009; Hwang & Tsai, 2010; Rogers et al., 2005; Wu, Hwang & Tsai, 2013) have

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become dynamic and active research areas in recent years which have resulted from the technological development, too.

After Starner (2013) introduced Google Glass to the academic community, research in the field of activity recognition showed that Google Glass provided new ways of improved activity recognition, by detecting and analyzing users' blink frequency (Ishimaru et al., 2014) with its built-in proximity sensor. While using Google Glass as an experimental tool for physics experiments is new, this project relates to an extremely dynamic trend in physics education: using internal sensors of everyday modern communication technology as experimental tools (brief summary: Kuhn, 2014; column for examples on high-school level: Kuhn & Vogt, 2012; implementation in university curriculum: Klein et al., 2015). The method described here takes previous research into new directions by using the specific features of Google Glass. Without adding much obtrusiveness and social awkwardness, we will move from the classical HMD vision with only a near-eye display to novel, elaborate sensing and interaction concepts of head-centered, wearable-technology enhanced learning.

2. Theoretical Background and Rationale

It is well known that competent handling of multiple representations is significant for learning and solving problems – especially in science education (Ainsworth, 1999 & 2006; Dolin, 2007). Furthermore researchers have found that integrating multiple representations (especially visual ones) enhances the conceptual learning environment for many students (Dori & Belcher, 2005; Gilbert & Treagust, 2009; van Someren, Reimann, Boshuizen, & de Jong, 1998).

A psychological model for understanding the cognitive processes while working with multiple representations is offered by the Cognitive Theory of Multimedia Learning (CTML; Mayer, 2005) and the Cognitive Load Theory (CLT; Chandler & Sweller, 1991). Referred to as CTML, the generation of a mental model of learning content requires an active part in information processing. The presentation format of the learning material is essential and can be structured into text / picture or classified according to dynamics and interactivity (Girwidz et al., 2006a; 2006b). Students' learning is improved by presenting text and picture / video instead of learning with text alone. While using the pictorial and verbal channel simultaneously, sensory and representational differentiations are connected and, as a result, cognitive load is reduced (multicoding). Hence, capacity of working memory is available for germane cognitive load in order to form mental representation models according to CTML and, therefore, learnability is increased.

Besides the importance of multiple representations for better learning, it is presumed that curiosity is one of the three pillars of academic performance (von Stumm, Hell & Chamorro-Premuzic, 2011). By Using Google Glass as experimental tool in the way described above, the interaction with this mobile device could provide a new means of exploring scientific phenomena.

In principle all of the above (and other) sensing and interaction modalities could be integrated around an unobtrusive HMD frame, extending the HMD system towards the vision of head-centered, context-aware computing. Using Google Glass as an experimental tool in the way described below (see 3.1 and 3.3) offers the possibility to work actively with different representational formats simultaneously, e.g., line diagram, bar graph, symbols, scale reading. Parallel to the near-eye presentation of multiple representations, students can still conduct the experimental tasks with both hands.

Based on the theoretical framework and the rationale mentioned above, we hypothesize that wearable-technology enhanced learning with Google Glass

- fosters curiosity, motivation, concept learning as well as representational and experimental competencies, and
- reduces cognitive load.

In this first study, we focus on the implementation of Google Glass as an experimental tool in undergraduate regular physics teacher education courses and study the variables curiosity and cognitive load in a first step.

3. Material and Methods

3.1. Experimental Procedure

The core idea is that the students fill the glass with water and test the frequency while, at the same time, Google Glass incrementally generates a graph showing the relationship between fill level and frequency. When water is filled in the water glass, the frequency of the tone lowers. This happens because as water is added more mass is added to the water glass. More mass results in a smaller/lower vibrating frequency, and less mass produces a faster/higher vibrating frequency of the wall of the glass. Noticeably, the phenomenon that students should detect is that the pitch does not correlate linearly with the fill level (see Figure 1.), contrary to what they might have assumed based on their everyday experiences. Until the water glass is nearly half-full, the pitch changes less when a fixed amount of water is added compared to when the water glass is nearly full. Thus the student can view the results on the display as the experiment evolves (while he fills/removes water into/from the glass).

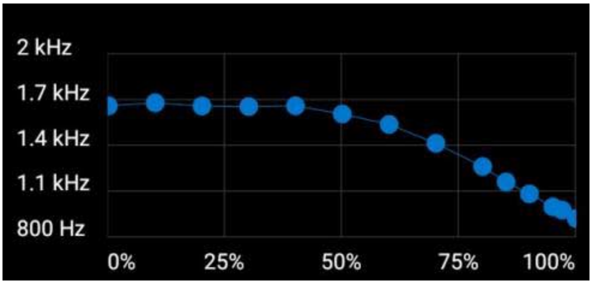

Figure 1. Measuring the relationship between the fill level of a glass of water and the resulting tone example with Google Glass. Screenshot of the gPhysics App after finishing the experimental task.

As shown in Figure 2 the gPhysics app was developed as follows: It first requests input of the fill level, which can be entered by voice, by a head-motion-driven slider (with an eye blink as confirmation) or by automatically using the built-in camera (again with an eye-blink confirmation). The students then access the measurement menu. They hit the glass with the wooden peg and the generated tone is analyzed by the built-in Glass microphone until the app has detected the tone three times with no or only small deviations. The current frequency is added to a diagram displaying the water fill level (x-axis) and frequency (y-axis). The procedure is repeated until the student has recorded enough points to calculate the dependence.

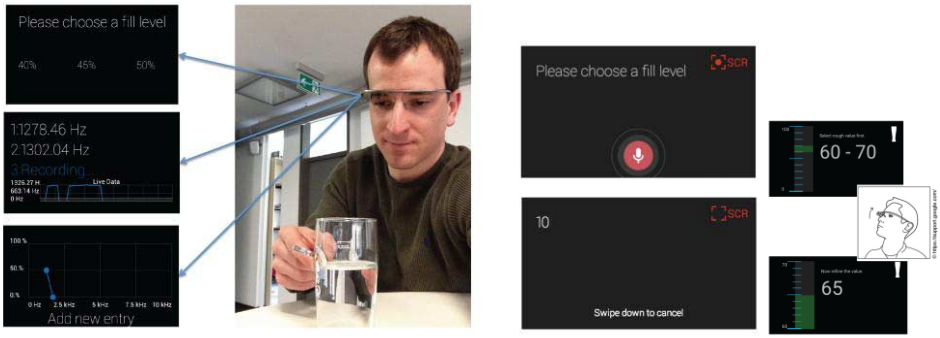

Figure 2. Left: The concept of the gPhysics education app with users inputting the water level in a glass, striking it to generate sound, which the Google Glass device analyzes, and obtaining a real-time plot of the fill level-frequency dependence. Right: Different input modalities are shown: (1) voice input, (2) level input through head inclination with eye blinking for confirmation, and (3) automatic recognition with the Google Glass camera.

We implemented the Google Glass application with the Glass Development Kit (GDK), an add-on of the Android SDK which enabled us to build Glassware running directly on Google Glass (as opposed to Google Glass Mirror API which does not allow full hardware access and interaction). The visualization and input (including eye-blink and head-motion detection) build on the provided routines. The image processing is implemented with OpenCV computer vision libraries and essentially consists of two stages: first, the detection of the fluid color component and, second, the detection of the colored labels and estimation of the filling level. We used a bright green fluid created with green food coloring and five orange stripes with their upper edges aligned with 100%, 75%, 50%, 25%, and 0%. Originally we implemented the entire detection to run on the Glass device. However, together with the sound processing it made the system overheat and we had to transmit the images to an external computer for processing. The resonant frequency detection algorithm is a multi-step pipeline process that forwards the provisional results to the next stage following the subsequent series of steps: reading audio buffer, applying Fast Fourier Transformation, filtering frequencies between 650 Hz and 2000 Hz, detecting frequency with highest magnitude based on power spectrum, validating detected frequency with a magnitude threshold (0.5), detecting sequential ascending, resonant and descending values in window sequence. If a sequence is valid, it computes a resulting frequency value. If a sequence is invalid, it searches for a new valid sequence.

3.2. Study Sample

To study students' cognitive load and curiosity when using Google Glass as experimental tool with the gPhysics app in this context, ten randomly sampled physics teacher students examined the relationship between the fill level and tone frequency equipped with Google Glass (TG: treatment group) while ten other randomly sampled physics teacher students explored the relationship with a tablet PC (CG: control group). Both groups had the same cognitive and motivational pre-conditions as well as the same degree of experience with using mobile devices such as smartphones or tablet PCs as experimental tools (as they had previously attended the same experimental courses).

3.3. Study Design

In both cases (TG and CG) the tone generated by hitting the water glass was detected with the microphone of the mobile device. While the TG students were equipped with Google Glass and the gPhysics app, the CG used iPads and the SpectrumView Plus app (for iOS) as the best comparable case.

Before starting the experiments, the students were shown how to use the mobile devices and their apps separately in each of the groups (duration: 45 minutes). This introduction included a presentation of the relevant functions of the devices and their apps (duration: 15 minutes) followed by a 30-minute period during which the students autonomously measured five given, but different measurement examples.

Table 1. Detailed steps of the experimental procedure of TG and CG

Google Glass group (TG)	Tablet PC group (CG)
1. Fill the glass with an amount of water. 2. Indicate the water fill level by tip (1st glass) resp. blink (2nd glass) 3. You are now in the measuring menu. Hit the glass with the wooden peg until the app has detected the tone three times. Note: In case of invalid measurement, repeat steps 2 und 3. 4. In case of valid tone detection, the current frequency is added to a diagram displaying water fill level (x-axis) and frequency (y-axis). Chose the option "Add new entry" and repeat the procedure until 12 frequencies have been correctly detected. 5. Have the displayed graph checked by the instructor. 6. Change glass 1 and repeat the procedure with glass 2.	1. Fill the glass with an amount of water. 2. Hit the glass with the wooden peg and record the spectrogram of the tone. 3. Read out the smallest frequency with the highest intensity. 4. Fill the measuring value in the given table. 5. Repeat the procedure until 12 frequencies have been detected. 6. Transfer the value table to the given diagram. 7. Have the plotted graph checked by the instructor. 8. Change glass 1 and repeat the procedure with glass 2.

After the introduction, the students in both groups individually studied the relationship between the fill level of the glass of water and the resulting tone after hitting two different glasses (see Figure 3). While the overall experimental procedure was identical in both groups, the actions differed in some details because of the handling of the two mobile devices and their apps (see Table 1). An overview of the study design is presented in Table 2.

Table 2. Study Design

Time	Google Glass group (TG)	Tablet PC group (CG)
45'	Introduction to using Google Glass and the gPhysics app	Introduction to using the iPad and the SpectrumView Plus app
45'	Study the fill level-tone frequency relationship with Google Glass	Study the fill level-tone frequency relationship with tablet PC
10'	Post-test: curiosity, cognitive load	

The experimental time required by the students to study the phenomenon for each of the two glasses was recorded individually in each group. After finishing the experimental procedure (studying the phenomenon with two different glasses), we measured curiosity and cognitive load with well-established paper-and-pencil tests (Chandler & Sweller, 1991; Litman & Spielberger, 2003).

Figure 3. Students in our study performing the water glass experiment with Google Glass.

4. Results

Because of the small sample size, we will interpret the descriptive data of the conducted paper-and-pencil tests very conservatively and carefully. Figure 4 shows that the two groups differ in their degree of curiosity state. Students who experimented with Google Glass have a higher degree of curiosity state than students in the CG. Using the nonparametric Mann-Whitney test for independent random samples, we established that these differences are significant and with a large Cohen's d effect size ($p = 0.005$; $d = 1.1$).

However, the Mann-Whitney test showed no significant differences concerning the perceived cognitive load (concerning experimental demand and mobile device handling; $p_{\text{experiment}} = 0.8$; $p_{\text{device}} = 0.2$).

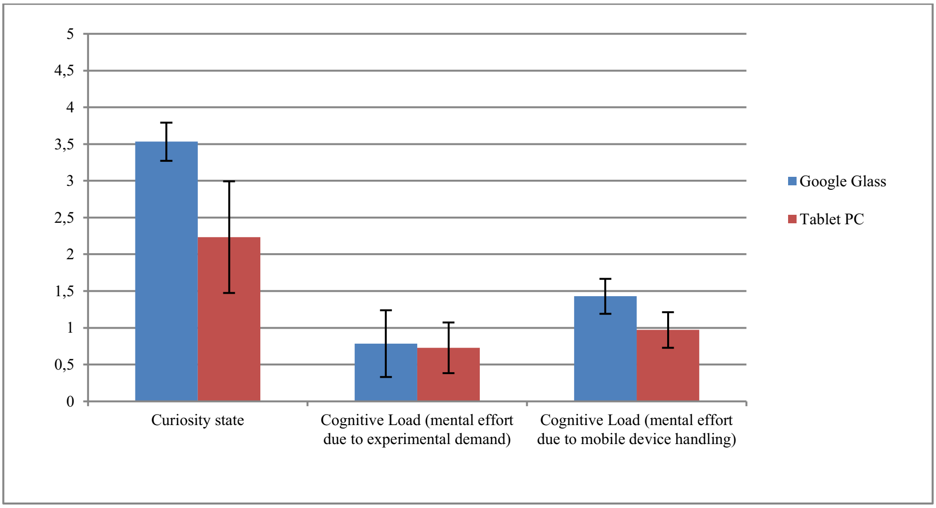

Figure 4. Mean and standard deviation of the curiosity state and the cognitive load of the two groups after experimentation with Google Glass resp. tablet PC (0: small; 5: high).

5. Discussion

The paper reports on a smart glass application and a related experiment that evaluates how cognitive load and curiosity are affected by the use of a digital performance aid when conducting a physics experiment. The findings indicate that curiosity is indeed affected by the app and device use, while the cognitive load is not significantly different from that experienced by the control group working with tablet computers. However, due to the small sample size as well as the special sample and topic, further studies have to be conducted. We are already preparing this topic for high-school students and are planning to expand the content to other topics in physics.

Without adding much obtrusiveness and social awkwardness, we move from classical HMD vision of having only a near-eye display to novel, elaborate sensing and interaction concepts of head-centered, wearable-technology enhanced learning.

In light of progress in miniaturization and sensing technologies, unobtrusive HMD platforms can be extended to tap a broad range of sensing and interaction possibilities associated with the head and face. This will lead to a novel class of context-aware interaction platforms and ultimately make the concept of head-mounted computing viable for everyday consumer use. While today‘s devices such as Google Glass are only beginning to tap this potential, we have shown that they can already be used for novel and interesting applications in educational settings – especially in physics, because of the possibility of using the internal sensors of the HMD such as the microphone. While Google Glass is currently being discontinued, various similar devices are available such as the VUZIX M100 smart glasses or Epson Moverio. A second generation of Google Glass is also said to be in the works.

Therefore we will continue extending our work by using further types of HMD as well as by developing experiments for other topics in science in general and physics in particular.

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Observing, Coaching and Reflecting: A Multi-modal Natural Language-based Dialogue System in a Learning Context

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Abstract. The Metalogue project aims to develop a multi-modal, multi-party dialogue system with metacognitive abilities that will advance our understanding of natural conversational human-machine interaction and dialogue interfaces. This paper introduces the vision for the system and discusses its application in the context of debate skills training where it has the potential to provide learners with a rich, immersive experience. In particular, it considers a potentially powerful learning analytics tool in the form of a performance reflection dashboard.

Keywords. Natural conversational interaction, mixed-reality, multi-modal dialogue systems, immersive, debate skills, learning analytics, reflection

1. Introduction

As we move towards a world of smart and immersive environments we are seeking new ways of interfacing and engaging with our technologies that more closely reflect natural human interaction. Human to human communication embodies multiple modalities such as speech, gesture, facial expressions, gaze, and body posture, so it follows there is an inherent desire to communicate with our technologies in the same way. This aspiration was illustrated recently in Spike Jonze' film 'Her' [1] in which a writer encounters 'Samantha'; a multi-modal dialogue system capable of understanding, expressing, and responding to emotion to the extent that it was possible for him to fall in love. While at present this level of immersion and engagement remains in the realms of science fiction, one of the aims of Metalogue, a three-year EU project, is to push the existing boundaries further in this direction.

So where to start? Absolutely free natural interaction is clearly not feasible at this point; however, educational dialogues and tutoring interventions offer some valuable

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constraints. The application of multi-modal, natural language interfaces in this domain is already being explored, for example Nye et al [2] text and speech, Johnson and Valente [3] discourse with "virtual humans", and Yang et al [4] use of motion sensors; however, increasing computing power offers the possibility of combining a range of traditional and new modalities in a single dialogue system. In this paper we will outline the proposed Metalogue multi-modal dialogue system and a potential application in the domain of debate skills training. It has been shown that digital immersion can enhance learning in three ways: by providing (1) multiple perspectives; (2) situated learning; and (3) transfer [5,6,7]. While the vision for the Metalogue debate skills trainer may not be considered "digitally immersive" in the traditional sense, it can be said to offer an augmented reality that would incorporate these three types of experience.

We start with an outline of the physical system and details of its composition, we then describe its implementation in the form of a debate skills trainer and discuss, in detail, learning analytics and the design for reflective feedback. To close we review Metalogue's immersive potential, and finally layout plans for the implementation and evaluation of the vision.

2. Metalogue: A Multi-Modal, Multi-Party Dialogue System

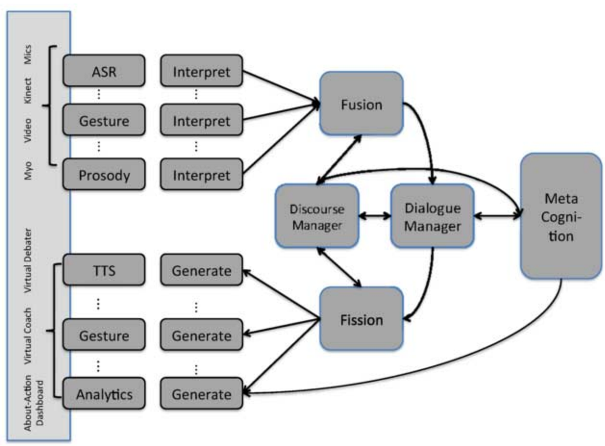

Figure 1. Metalogue components and workflow.

Metalogue is designed to "hear" and "see" a wide range of human interaction signals, and to "interpret", and "respond" in as natural way as possible, either in a coaching capacity or as a fully-fledged partner in the interaction. Figure 1. depicts the integrated components of the system and its processing workflow. Metalogue gathers three types of sensor specific data [8] that serve as input: (1) speech signals from multiple sources (wearable microphones and headsets for each dialogue participant and an all-around microphone placed between participants); (2) visible movements tracking signals from Microsoft Kinect and Myo sensors capturing body movements and facial expressions; and (3) video signals captured by the camera and recording the whole dialogue including sound.

The speech signals serve as input for two types of further processing: (1) Automatic Speech Recognition (ASR)[2], leading to lexical, syntactic and semantic analysis and ultimately updating the discourse model to answer the question 'what was said?, and (2) prosodic analysis[3] which is concerned with rhythm, stress and intonation of speech and answers the question 'how was it said?' This enables the system to interpret elements such as speech rate (fast, slow, adequate tempo), volume (loud, soft, adequate), emphasis (flat intonation, uneven/unbalanced intonation etc.), and pausing (too long or not enough). Analysis of visible movements gathered by Microsoft Kinect and Myo sensors, enable the system to interpret input related to gaze (re)direction, head movement and head orientation, facial expressions, hand and arm gestures, posture shifts, and body orientation. These outputs are further analyzed to determine factors such as emotional state and, ultimately, argument content, organization and delivery.

At the heart of the system, interpretation and the generation of output depend on advanced linguistic multi-modal, multi-party and multi-perspective discourse models. These combine both social and linguistic signal information and are generated by collecting and annotating a corpus of human-human interaction data. This, in turn, is used to train machine-learning algorithms for the automatic recognition and prediction of a wide range of human interaction phenomena. In addition, the system incorporates metacognitive models that explain metacognition as a set of skills, a cognitive agent that exhibits metacognitive behavior similar to humans, and a learner model able to assess the users' metacognitive skills. Together these aspects of Metalogue enable the system to critically analyse participants' interactions within a certain time frame and generate "events" (i.e. points highlighting areas where performance could be improved and positive interaction behaviors that can be built upon). These are recorded in the form of annotations to the video file.

Output to the user can take three forms; (1) in-performance coaching; (2) post-performance reflective analysis; and (3) an optional debate or negotiation partner in the form of a virtual character that simulates a wide range of both verbal and non-verbal language attributes.

3. Debate Skills Training:

To debate successfully the student must master a range of metacognitive skills [9, 10], such as monitoring and adjusting verbal performance, eye contact, body posture and gestures, also they must know when and how to employ appropriate strategies and arguments to achieve certain goals while at the same time recognising and responding to the oppositions' strategies and arguments. Debate skills training typically involves ad-hoc face-to-face classroom debates combined with more formal organised

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[2] The Metalogue ASR system is developed based on the Kaldi (http://kaldi.sourceforge.net/about.html) open-source speech recognition toolkit. The current trained system after augmenting general language models (trained on Wall Street Journal corpus) with a Speaker Adaptive Training using collected Metalogue data lead to a word error rate (WER) of approximately 32%.

[3] OpenSmile audio analysis tool has been used: http://records.sigmm.ndlab.net/2015/01/opensmile-the-munich-open-source-large-scale-multimedia-feature-extractor-a-tutorial-for-version-2-1/

competitions. While the learner gains confidence through these performances, feedback from tutor or panel on such complex combined physical and mental skills played out over a period of time, depends on subjective human judgment and may reflect a summary of the interaction rather than pinpoint specific behaviours that can be improved.

Implemented to support debate-skills training within a 4C-ID pedagogic framework [11], Metalogue allows the learner to debate with another human being or with a virtual debate partner and be subject to multi-channel digital “observation”. It further enhances the learner’s debate experience by providing real-time feedback currently envisaged in the form of signs and symbols displayed on a screen [12] indicating simple posture, volume or tone adjustments to improve performance. A wide range of performance analysis is constantly being generated by the system but real-time feedback is carefully balanced to avoid cognitive overload and/or disengagement whilst the learner is performing. The full range however can be accessed via a reflection dashboard that enables both tutor and learner to review and analyse the performance moment-by-moment. Metalogue will support the debate skills training with a consistent feedback loop, i.e. real-time feedback to raise awareness of currently trained aspects/behaviours and about-action feedback to trigger reflection on the previous training sessions and prepare for the following training sessions.

4. Learning Analytics: About-action Feedback

The term Learning Analytics generally refers to the large-scale measurement, collection and analysis of learner data across different systems within learning organisations [13]. Here we use the term to refer to the measurement, collection and analysis of Metalogue generated learner data relating to the individual learner, including comparisons with aggregated learner data from within the system. This type of reflection and analysis can support educational stakeholders in becoming “aware” of their actions and learning processes. Endsley [14,15] described being “aware” as a three level process consisting of the perception of elements in the current situation, the comprehension of the current situations and the projection of a future status. These three steps are seen as a prerequisite for making decisions and effectively performing tasks. Once people are aware of their situation, they can reflect on their actions, choose to adapt their behavior if necessary, and engage in a process of continuous learning [16].

Schön [16] defines reflective practice as the practice by which professionals become aware of their implicit knowledge base and learn from their experience. He uses the terms reflection-in-action (reflection on behaviour as it happens, so as to optimize the immediately following action), and reflection-about-action (reflection after the event, to review, analyse, and evaluate the situation, so as to gain insight for improved practice in future). In the context of the Metalogue project we refer to the system generated coaching feedback delivered to the learner during their debate performance as the in-action feedback, and the post performance reflection and analysis capabilities of the system as the about-action feedback. The in-action capabilities of the system have been outlined above; however, here we discuss our vision for the about-action reflection dashboard based on two user scenarios: (1) immediate post performance review by tutor and learner together; (2) tutor or learner individually reviewing at leisure.

There are a wide variety of software offering tools available to analyse and/or visualise existing data [17]. However, of particular interest in the context of the Metalogue project is the use of visualisation tools as demonstrated by the Flashmeeting project [18]. Although the application has been developed to support online meetings, the analysis tools provide a useful illustration of how a multimodal system data and analysis could be organized in the form of a reflection dashboard. For example, it is possible to replay the complete interaction, visualising the actual video replay as well as the broadcasting distribution over time (i.e. who spoke when and for how long), and more detailed information such as chat events, specific content annotations, and broadcasting events such as interruptions. It is also possible to view analyses such as broadcast dominance (i.e. the ratio of contribution by the different participants) in the form of a pie chart, and analysis of the interaction content in the form of a key word cloud.

The key criteria for the visualization of Metalogue data are:

- Occurrences of an event (e.g. voice volume (too high, too low etc), confident posture) on a timeline
- Aggregation of a single event (e.g. time used)
- Occurrences of a number of events in relation to each other in time.
- Integrated overview of various events.

In addition, parts of the dashboard may need to be layered, particularly when an integrated event is shown, and the learner or tutor should be able to zoom-in into the underlying aspects for further clarification.

5. The Metalogue About-action Dashboard: An Outline Design

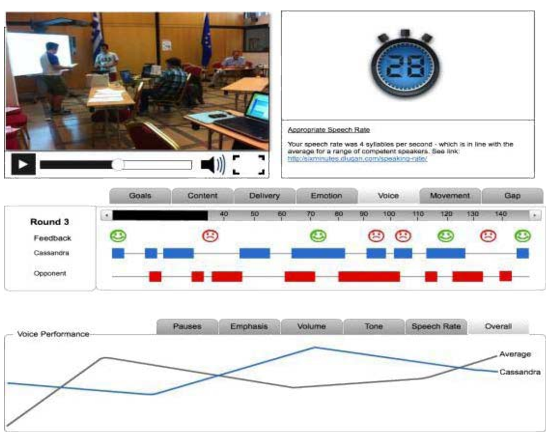

Figure 2. Metalogue About-action Dashboard screen mock-up.

An example of the type of about-action analysis the Metalogue system can provide the tutor and learner is shown as a screen mock-up in Figure 2. There are a wide range of options for selecting and viewing the whole or segments of the learner's performance during a debate round. Video material appears in the top left window with standard video controls immediately beneath. Below (central) is the timeline adapted from the Flashmeeting dashboard as discussed above. This shows the utterances of both the learner and her opponent, plus the Metalogue feedback events against the timeline of the video. Clicking on an utterance block or an event symbol will display the corresponding video segment in the top left window. Similarly, clicking a particular point on the timeline will locate that point in the video.

The tabs along the top of the timeline window allow the user to view different types of event symbol; for example, Figure 2 (central) shows the voice tab has been selected. Accordingly, the symbols along the timeline represent all the Metalogue feedback events relating to voice performance. As the video plays, the top right window displays in detail any feedback events located on the timeline, this includes feedback given in-action, i.e. during performance, and all other events detected by Metalogue during performance but not displayed at the time to avoid overloading the learner. In Figure 2 the feedback is shown as a stopwatch symbol, providing positive feedback to the learner that her speech rate at this point was at an ideal level. It also provides clarification of what the symbol represents and provides links for further exploration.

The lower window is intended to provide various kinds of analysis depending on the tab selected on the timeline window above. In this case, with the voice tab selected (Figure 2, central), the available analysis options for voice are displayed along the top of the lower analysis window i.e. pause, emphasis, volume etc. The 'Overall' tab is shown as selected (lower-right) and the window displays an analysis of the learner's voice performance for the round against the average performance of other learners training with the same game parameters.

6. An Immersive Experience?

Debate, whether human-human or human–virtual human, is by its very nature immersive; however, returning to the "digital immersion" criteria [5,6,7] mentioned in the introduction to this paper (i.e. situated learning, multiple perspectives, and transfer), we will review the proposed Metalogue functionality.

With regard to situated learning, the debate trainer is being designed to support the 4C-ID pedagogic framework [11] which mandates attention to authentic whole tasks based on real life, organized in classes with variation and increasing complexity. The leaner experience is also dynamic and engaging, with the system taking the role of observer/audience and coach. In addition, it offers the option of a virtual debate partner able to employ natural language interaction and different styles of delivery (e.g. aggressive, conciliatory etc.).

Both in-action and about-action feedback offer the learner multiple alternative perspectives on their performance enabling them to become aware of certain behaviours and make choices about how to respond when necessary. For example, in-action: resetting body posture that has become inappropriate or gaze that has become averted; about-action: recognizing and understanding debate strategies and how to employ them.

Finally, in terms of transferability, Metalogue is a mixed-reality system therefore the context of the learner is never entirely removed from the real world. Also the simulations involve realistic debating scenarios that allow the tutor to determine the topic and set the extent of the challenge, thus learning outcomes are envisaged to be highly transferrable.

7. Vision Into Reality

The Metalogue project will be realised in three incremental prototype development cycles culminating in the full functionality outlined in this paper. The first prototype has now been integrated and is currently able to hear and observe learner interactions and provides real-time feedback on posture, hand/arm gestures, and voice volume. This is the first step proving the basic Metalogue concepts from a technical perspective. Each pilot will be comprehensively evaluated with "real learners" in the form of debate students from the Hellenic Youth Parliament. It will involve the technical evaluation of the multi-modal dialogue system (employing user-based and non user-based techniques), user evaluation and satisfaction measurements, and learning effectiveness measurements. Alongside the application of Metalogue as a debate skills training system, the project will pursue its potential application in a call-center environment supporting agent training, and furthermore, investigate its portability into different languages.

The vision elaborated above is a challenging, multi-disciplinary endeavor and a work in progress. However, the outcomes have the potential to advance our understanding of debate training and learning analytics on one level, and conversational human-machine interaction, dialogue interfaces on another – perhaps moving us one small step towards the visionary capabilities embodied in Jonze' Her [1].

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OSCase: A data scheme for transfer of Web based Virtual Patients to OpenSim

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Abstract. Experiential game based learning has proven effective at engaging and enabling learners especially in medical education where the volume of the curriculum is as severe as its criticality. A mature and promising ICT tool for medical education is the Virtual Patient (VP). Web-based virtual patients have been established for quite some time, while efforts have been made to create content in multi user virtual environments (MUVEs). What is still missing is a streamlined method for transferring VPs from Web-based authoring and deployment platforms to MUVEs like OpenSim. This work describes the existing implementation context for repurposing VPs in the OS MUVE. Then it focuses on a novel OpenSim Case Datascheme (OSCase) that facilitates this streamlined transfer according to previous repurposing strategies and efforts. Finally the future directions and the place of this work in the wider context of contemporary Virtual Learning Environments is explored.

Keywords. Virtual Patients, Mutliuser Virtual Environments, OpenSim, OpenLabyrinth, medical education, Content repurposing.

1. Introduction

Massive content increase in medical education [1] as well as the criticality of the subject matter has led contemporary medical education to move into diverse activities and resources that become increasingly digital [2]. The underlying goal of these efforts is ubiquitous access to clinical skill development tools [3]. Web and Information, Communication Technologies, thus, become key enablers in medical education providing the tools for developing interactive, immediate learning environments independent from location and time constraints [4].

A very promising ICT tool for enabling medical education is the Virtual Patient (VP). It has been formally defined by the MedBiquitous Consortium as “interactive computer simulations of real-life clinical scenarios for the purpose of medical training, education, or assessment” [5]. Its importance was immediately identified with efforts being initiated and formalized into an International Standard for exchangeability purposes for several years now [6], [7], [8]. The acceptance of the VP with platforms enabling Web based streamlined development and deployment has facilitated diverse learning episodes and modalities such as lectures, exams, project/problem–based

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learning as well as both synchronous and asynchronous e-learning sessions [9]. VPs' proliferation has led to endeavors of specializing and contextualizing their design models even down to particular medical specialties [10].

This proliferation of VPs led to the development of several VP authoring and deployment platforms. One such, widely spread, platform is OpenLabyrinth (OLab) [11]. OLab is defined in its user guide as "…an open source online activity modelling system that allows users to build interactive 'game-informed' educational activities such as virtual patients, simulations, games, mazes and algorithms. It has been designed to be adaptable and simple to use while retaining a wealth of game-like features." [12]. It is a web based tool that is accessible through most contemporary browsers with minimal hardware requirements and with an acceptable learning curve. This accessibility makes it suitable for deploying content for testing new learner-centered educational approaches.

Advances in presentation with game-like 3d Multi User Virtual Environments (MUVEs) have led to the deployment of VPs in them in order to increase immediacy, impact and the user's sense of presence [13], [14]. A MUVE's definition can be construed as identical to that of Virtual World: "A synchronous, persistent network of people, represented as avatars, facilitated by networked computers" [15]. This definition inherently demonstrates the educational advantages of this platform. Persistent and synchronous networking is a significant collaboration facilitator. The graphical representation of the user in customizable human likeness creates a sense of presence and immersion [14] that is inherently assistive towards engagement in various educational (or not) goals.

This work is based on current achievements in our efforts at repurposing VPs into the OpenSim (OS) MUVE. Having established a streamlined way of presenting individual VPs in this environment as point and click adventure episodes we present here a data scheme to facilitate automation in the repurposing of VPs from the popular OpenLabyrinth (OLab) platform to the OS MUVE platform. The rest of this paper is organized as follows. In the next section we describe the current status of our VP repurposing efforts both within the OLab platform and the lessons learnt from manually repurposing cases from OLab to OS. Based on this context, then, we present the data scheme that will be used to become the link between the OLab data infrastructure and the OS VP deployment mode that we have chosen to implement. In the final section the immediate future steps of this work are explored and the implication in the wider context of medical education research is discussed.

2. Implementing VP repurposing.

2.1. Repurposing Web based VPs in content and context

On one axis the repurposing efforts taken involved the extension of the mEducator metadata scheme [16], [17] in order for it to become applicable in OLab creating its semantically enriched extension, OLabX. This semantic enrichment allows VPs to be discoverable, sharable and searchable for ease of repurposing. OLabX has extended the metadata that describe a VP (Labyrinth) through the existing OLab Global Metadata Editor in order to cater for the provisions in the mEducator schema.

This schema defines metadata accompanying an educational resource, in our case a VP [16]. The metadata are highly structured supporting reusability and repurposing of the resource [17]. Its implementation provides advanced repository functionalities that were not present in the core OLab tool. Contextual content query, with synonym identification as well as rudimentary analytics in the form of past user preferences are the main features that separate OLabX from the core version. Additionally, the open architecture of the scheme through the utilization of existing end established medical vocabularies ensures the extendibility capacities of OLabX through implicit RDF referencing. The details of the OLabX metadata scheme have been extensively described elsewhere [18].

2.2. Repurposing VPs to MUVEs

On a parallel axis the repurposing efforts taken involved the “cross-environment” migration of VPs from the Web to MUVEs. Efforts included both a dental VP [19] and training scenarios for carers of the elderly [20]. While the subject matter was in widely different areas of the overall healthcare field, the technical specifics were the same. The cases were deployed initially in Second Life and then in OS both in the form of a point-and-click adventure. The user feedback came mainly through chat messages. The user guided the action through either multiple choice notecards on which the user had to make one choice or through simple choice of items, by clicking on which, the user declared his intended action as described by the cases’ narrative (**Figure 1**)

Figure 1 A multiple choice notecard for receiving the input of the user in OpenSim deployed VP.

In all cases the VP trees were implemented to the OS MUVE verbatim as they were initially deployed in OLab. Constraints such as time limits were removed because the focus was on the assessment of implementation and usability and not so in the efficacy of the case as an evaluation tool. Most of the choices that the player made were narratively evaluated and the user was given the opportunity to retry in order to avoid unnecessary frustration.

Technically, all the VP simulation was implemented through the OpenSim Scripting Language (OSSL). All the appropriate Web resources (eg, images) were stored in a lab server. OSSL is an event/state-based language. Scripting utilizes events, such as clicking, listening for chat messages, or deploying items in the world. Using these events as triggers complex interaction scenarios can be coded. The activities of the case were coded as events that triggered as the user interacted with the environment by touching pieces of it and receiving challenges in the form of multiple-choice questions. The user's response triggered additional events that led the case to move to the next relevant state/node. Additionally, all the patient data, narrative, values, or external media references were stored in the case script as global variables. Each in-world object contained its own script that communicated with the main simulator scripts to facilitate interaction through clicking on objects.

In order for this model to cater for technical limitations (e.g. maximum script file size) as well as following OLab's implementation logic, virtual "nodes" were created in OS too. These are, in-world, invisible and intangible objects, containing scripts that implement all the connectivity logic and present the case's narrative to the user. Communication between these nodes was realized through simple chat message exchange in predetermined chat channels of OS. While the user experienced the case as an interactive point and click adventure clicking at designated points, receiving feedback and making choices, these activities were an interactive navigation of this virtual node tree through clickable objects and multiple choice notecards. All nodes consisted of these two script types and between the nodes of the same type differences existed only in variable values (narrative strings, navigation node id numbers etc). In this way, from a technical point of view, implementation time was reduced and debugging was facilitated. Furthermore this implementation ensured maximum reusability of script assets and also presented the opportunity for implementing a data scheme for automated deployment of OLab VPs in OS.

2.3. The OSCase Datascheme

In the previous section the repurposing of VPs from the web to the MUVE have been described to provide context to the effort being made currently to automate the transfer and linking of OLab resources to the OS MUVE.

The overall approach of the OS Case Datascheme is outlined in **Figure 2**. Each OS Geometry Object is defined as the actual graphical asset, e.g. a house, a chair, etc as depicted in-world. This becomes part of the OS Asset Repurposing Archive and is assigned, through the OS Object datascheme the necessary attributes for unique identification. These include the URL of the Grid in which it belongs, its unique in world identifier – OS - UUID, OS Grid geometry localization (where it is and it's dimensions) as well as a designated channel that will be used for communication with this asset. Geometry Objects are distinguished between Assets and Environments in order to establish a basic hierarchy (e.g. a piece of Furniture is an asset that belongs to the Environment "Beach house") that can be used by content creators for meaningfully interpreting relationships between Assets. For example, if a user was to repurpose a VP and choose as environment a "Doctor's Office" there should be clarity about which assets of the database are technically in the same OSGrid and, thus, physically within the environment.

This OS Object datascheme is incorporated to the overall OS Case datascheme which also links to OLab's datascheme in order to facilitate the assignment of meaningful state/link pairings to each instance of use for each OS Asset that is utilized in the repurposing effort. Each of the significant entity types in OpenLabyrinth has its equivalent in OS. For this purpose, the data scheme includes classes like Labyrinth, Node and Link, which represent the same structure found in the original virtual patient. The mapping between the OpenLabyrinth entities and the OS Assets is realized through a set of interaction-related classes.

NodeNavigation is a wrapper around Node. An instance of this class is created every time the user navigates to a new node by following a link. The NodeNavigation instance is followed by an InteractionTriggerCollection which represents the outgoing links of the current node, introducing interactivity. Depending on the semantic properties embedded into the node, the InteractionTriggerCollection instance is implemented either as a NoteCardOptionCollection or a LinkBoxCollection to address the scripting implementation of either Notecard or clickable objects' nodes. The former is attached to an OS asset that triggers it and is followed by many NoteCardOption instances to show as message options in the OS Notecard. LinkBoxCollection, on the other hand is not attached to a specific asset, as it is followed by LinkBoxes that each is attached to the relative triggering asset (OS Clickable object). Both LinkBox and NoteCardOption can be seen as parts of an interaction setting where they are expressing the multiple navigation paths available starting from a labyrinth node. All communications between the MUVE and the web infrastructure shall be realized in JSON format.

The detailed description of the OSCase datascheme in UML is presented in **Figure 3** -**Figure 5**.

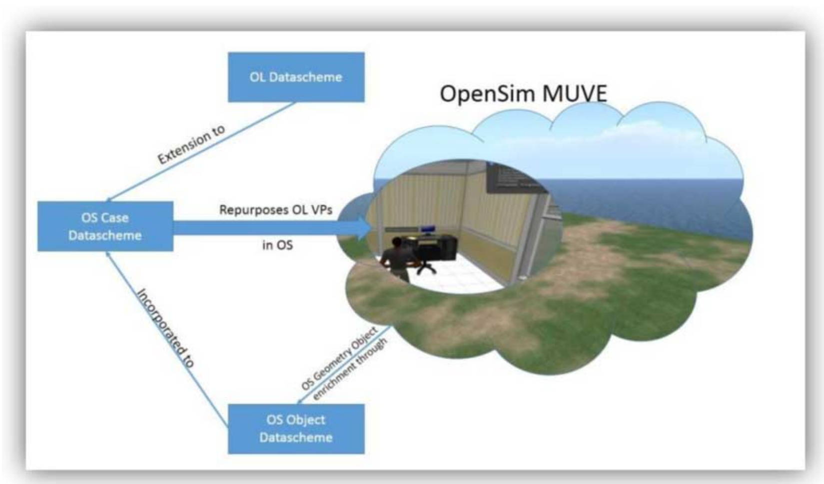

Figure 2 The overall approach of the repurposing effort from OLab to OS.

3. Discussion

The work presented here describes a datascheme that can readily be utilized for repurposing OLab deployed VPs in the OS MUVE. Efforts are currently directed in implementing a web based front-end for content authors to be able, through it, to rapidly repurpose VPs into the OS MUVE. Immediate steps after implementation include both usability and efficacy testing of this repurposing framework.

In online education the phrase Virtual Learning Environment (VLE) has changed meaning significantly. From the closed online repositories where instructors uploaded their content on strict access terms, to the world of today's MOOCs [21] VLEs are now envisioned as collaborative, decentralized, educational activity signposts that guide, albeit expertly, the participant to find appropriate content for organically achieving specific learning objectives. Content is delivered by an online infrastructure of tools [22] that is also decentralized and utilizes cloud computing [23]. Students are expected to participate in a MOOC as active collaborators. While the educational process may begin in the central MOOC hub, the core of collaborative educational action may shift to a student's personal blog or youtube channel [21].

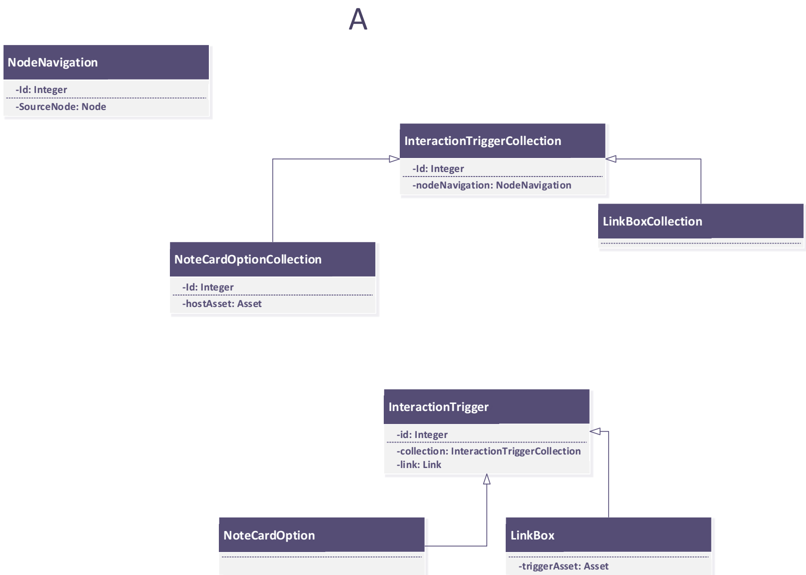

Figure 3 OS Case Datascheme A: The Relationships of the proposed datascheme.

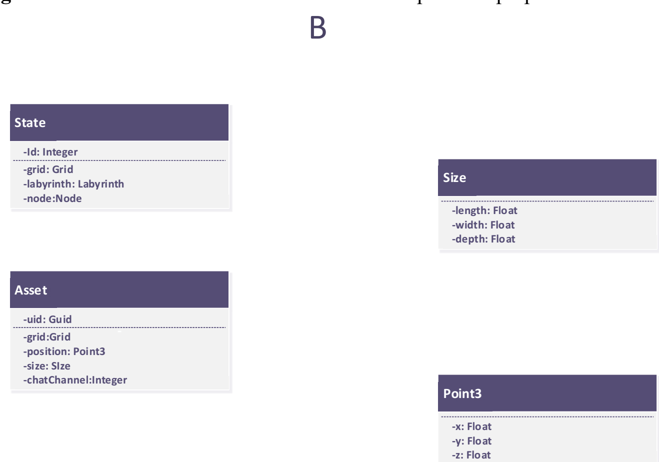

Figure 4 OS Case Datascheme. B: OpenSim side Description.

This paradigm of decentralization aligns well with the repurposing effort presented in this work. With the immersion potential, the capacity for collaboration and engagement of MUVEs as a given [13], [14], the inclusion of this educational medium in Massive Open Online educational endeavors appears as a natural evolution. The main barriers to such an evolution are the integration to the infrastructure and the creation of a non-trivial amount of quality content in this medium. However, with the aforementioned decentralization of the infrastructure, the integration problem becomes less important. With VPs as an implementation being around for almost 40 years [24] and OLab almost reaching a decade of existence [11] web based VPs can be considered a mainstream tool in medical education. Hence streamlining transfer of such cases to a MUVE can provide a significant content boost in MUVE VPs.

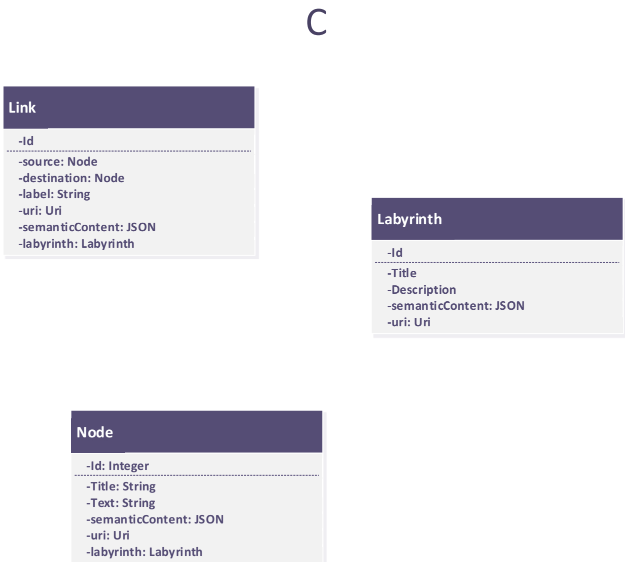

Figure 5 OS Case Datascheme. C: OLab-side inclusions.

This work is the first step towards streamlined repurposing of VPs into MUVEs and integrating this medium in the overall endeavor of contemporary VLEs. The feasibility of deploying web based VPs in VLEs such as MOOCs has been explored with promising results [25], [26]. While transparent accessibility of a MUVE through a web interface is still an issue, a more important issue is addressed by the current work, that is, rapid content development in the MUVE platform. The datascheme presented here aims to contribute in the evolution of that aspect of contemporary VLEs.

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The GhostHands UX: telementoring with hands-on augmented reality instruction

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Abstract. Augmented Reality is providing a whole new set of possibilities to improve proficiency and safety on the workplace and reduce costs during training, in particular in manufacturing and automotive industries. Among the applications developed to support workers on the shop floor, telementoring plays a leading role as a demonstrator of the capabilities of AR in industry. This paper explores the user experience of telementoring via GhostHands - the use of a virtual model of a mentor's real hands, appearing in a workers full AR view of a work task. The mentor can see the workers view 'through their eyes' and can place their GhostHands into that view. Both worker and mentor appear to cope with this 'ghost assisted' experience very well, and recognise a sense of joint accomplishment from the cues that the hands embody in completing a task.

Keywords. Augmented Reality, Telementoring, User Experience, Instruction

1. Introduction

Over the past ten years, one key driver behind the development of Augmented Reality (AR) technologies has been industrial and manufacturing contexts. In these environments, there are many advantages to overlaying real-time contextual information directly into the worker's field of view of the workplace, such as a increasing learning and work efficiency and improved awareness and safety. Considering the recent expansion of the market for "full vision" AR glasses, AR applications in the industrial context can now in principle be completely hands-free. One full vision application in particular, that is capturing the attention of both research community and industrial partners is 'telementoring'. The possibility to connect with a remote expert mentor who can support or train workers during their actual working performance is a very powerful idea.
Although these new channels of communication represent a great advancement in industry, they are usually a poor substitute for the physical real-time presence of a mentor. One of the most important challenges is that a physical human body in a physical workplace "embodies" many subtle learning cues. A worker can learn very effectively via the non-verbal observation of a mentor performing a manual task via subtle cues 'embodied' in eg. the position of the mentors hands, cued by the hands' position, angle, thrust, or safe movement. In this paper, we present GhostHands, a novel interaction concept that tries to fill this gap by overlaying on the worker's field of view the virtual hands of an expert – modelled in real-time, from the position of that expert's remote, real hands. The purpose of this paper is not to evaluate the actual effectiveness of the prototype application in terms of quantitative measurements of task completion time or error-rate trends, but to provide insight into the experience of users, on both ends of this interaction link. The user

experience strongly affects the effective adoption of a new technology and how it will impact, in this case, on work performance. The results of this study will be used to inform the design in the next development iterations of this concept.
Section 2 identifies background and rationale behind GhostHands. In Section 3 the application and its implementation are described in detail as well as the evaluation protocol. The results of the evaluation are reported in Section 4 and discussed in Section 5.

2. Related research

Through AR-enabled devices the worker can contact an instructor during difficult situations, such as wicked problems or complex tasks that require specialist knowledge, critical procedures involving safety concerns, or variations of configurations of machines that the worker has no direct knowledge of, hence requiring cross-training. In particular in non-standard cases, packaged AR applications fail to provide the needed support for effective problem resolution and remote collaboration is essential for the solution of the problem. Remote collaboration also remarkably improves proficiency of workers during manual labor [6]. In the past, many works have tried to explore the possibilities of AR-enabled remote mentoring. Zhong et al. [2] propose a prototype of an AR collaborative training application that creates a “shared” workspace in which the trainer can manipulate virtual objects overlaid on the trainee’s field of view. Interaction between users, however, was in this case limited to simple real-time audio conversation. Bottecchia et al. [3] propose an AR system for tele-assistance based on a new interaction protocol, that allows the instructor to point at objects, outline particular parts of it and apply 3D overlaid animations. Although granting to the expert a good level of interaction with the worker’s environment, this application is based on the assumption of having 3D models of all the machines and tools the worker is going to operate with. This assumption is not applicable in real-life use case, where third-party supplying companies are often not allowed to release such information. Similarly, a body-worn camera/laser pointer - named WACL - is proposed in [4]. WACL allows the expert to point and name objects to accelerate the collaborative work. An alternative approach is taken in [5]. In this platform, the “Adaptive Visual Aids” are visual post-its in the form of shapes, text or drawings that can be superimposed on the worker’s field of view independently from the object position and are shareable among workers in different tele-consultancy sessions. All the systems described suffer the following limitation: the identification of the worker with the expert. In a side-by-side working situation, the worker can see what the expert’s movement and gestures are, and acquire visual knowledge of the task by simply watching and then repeating. The current state of the art of AR applications does not offer an appropriate replacement for this learning channel. Moreover, it is demonstrated that workers perform better when the expert is physically present because of “their ability to gesture in the space to ground the conversation more efficiently” [1]. Gestures play a fundamental role in timing the conversation and reducing the stress caused by communication synchronisation. In addition, to facilitate the interaction, spatial indications such as “here” and “there”, or “this” and “that” are indispensable for an effective and comfortable discussion [7].

3. GhostHands

We propose a new interaction modality for AR-enabled telementoring: GhostHands. The prototype GhostHands AR application allows telementors to remotely stream a realistic

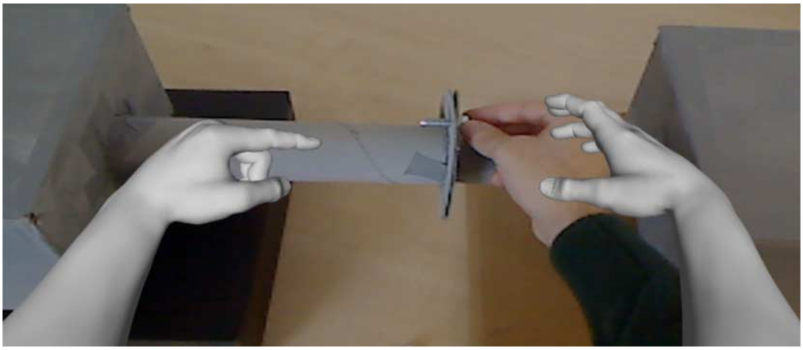

Figure 1. A screenshot of the GhostHands application.

model of their forearms+hands directly onto a worker's field of view. In addition to the shared visual space and the conversational audio communication via real-time video and audio streams, the mentor is able to interact with the worker through the direct use of hand movements and gestures.

GhostHands is composed of two separate intercommunicating applications. The expert-side application shows on a display the live video stream of the worker's environment. By means of an infrared sensor, the application captures the mentor's hand movements and reproduces them in real-time on the display using 3D models of human-like hands. The 3D models are overlaid on the video feed, so that the expert can constantly observe how their "ghost hands" are spatially positioned with respect to the incoming video stream. The mentor has complete freedom of movement and is able to perform a very wide variety of gesture within the worker's view, moving both their hands with six degrees of freedom. On the worker-side application, a head-mounted camera captures the live video stream that will be sent to the mentor side's counterpart, while a display shows to the worker the 3D modelled remotely-controlled hands in situ.

Using GhostHands the expert can virtually interact with the worker in a reaching "over-the-shoulder" way, performing many kind of actions:

- pointing at objects in the workers environment and naming them without the need of graphic pointers;
- signalling a danger;
- showing how to properly interact with objects performing the correct movements, demonstrating the proper hand's pose, angle and speed;
- performing gestures while talking.

The main advantage of GhostHands lays in the possibility for the worker to instantly mimic the expert's movement. The worker can virtually "fit" his/her hands in the expert's ones, immediately reproducing pose and movement that overlaid hands are performing. This produces a great benefit in terms of both kinaesthetic learning and procedure ergonomics. The virtual guidance provided by the expert through GhostHands can partially compensates his/her physical absence. In addition, with GhostHands the worker can simultaneously watch the hands instructing and perform the task, fitting his/her hands into the mentors ones like virtual gloves.

This interaction modality considerably benefits also situations where the workplace safety is at risk. Imagine a scenario in which a worker needs to face an unexpected situation of danger. A machine processing toxic chemical compounds suddenly stops working with the risk of material leakage and none of the workers in the facility knows the procedure. Using GhostHands a remote expert can supervise the procedure instructing a worker on actions to perform, maintaining the safety level high and avoiding the risk for the worker to incur in physically harming accidents.

The communication signalled by hand gestures is also highly relevant. Being able to perform spatial gestures greatly reduces the need for extensive and verbose descriptions of the environment around the worker, thus speeding up the communication between the two sides. Gesticulation is also a natural synchronisation interface in a face-to-face human conversations. Hence, the absence of this visual channel can cause stress and frustration. GhostHands offers to fill these gaps providing a natural, virtual interface to compensate the physical absence of the expert in the workers environment.

3.1. Implementation

Both expert-side and worker-side applications have been built using the Unity3D game engine. To capture the experts hand movement, the capabilities of the Leap Motion sensor has been exploited. This sensor projects infrared light from a USB-tethered device, capturing hand movements. The expert user hovers their hands over the device in order to use it. The Leap Motion SDK provides a WebSocket server that streams captured data to our the GhostHands service. To reproduce hand movements on the other end of the connection, this stream has been redirected via a Node.js server that bridges and regulates the communication between worker-side and expert-side application.

3.2. User eXperience evaluation

In the majority of the studies involving AR-enabled technologies and applications, research has so far primarily focused on investigating the advantages of AR in terms of performance improvement or, in some cases, on identifying issues related to usability or cognitive stress [8,9]. Generally, the AR research community lacks understanding of the aspects of user experience for AR demonstrators [10]. UX insights are, however, crucial if the community aims at delivering well-accepted services. For this reason, we considered necessary to perform a user-centered evaluation of GhostHands. The results of this evaluation will be fed in the following development iterations and will serve as a benchmark relative to user requirements and expectations. The overall objective of this work is to obtain insights on how the introduction of a natural communication interface, such as hands gestures, is perceived by users when channeled into a new technology like AR. To achieve this, some relevant questions need to be answered:

- How do GhostHands improve the worker's learning engagement?
- How do GhostHands affect the level of confidence of both the instructor and the worker?
- To what extent do users perceive the task facilitated by the usage of GhostHands?

User experience concepts are often neglected in interaction design. Disregard for human factors when designing a new interaction model, as GhostHands is, might result in side effects due to the failure of engagement into the new technology (e.g. visceral repulsion towards the technology and decrease in productivity). On the other hand, positive experiences and emotions related to the product improve users focus, facilitating and increasing well-being [11].

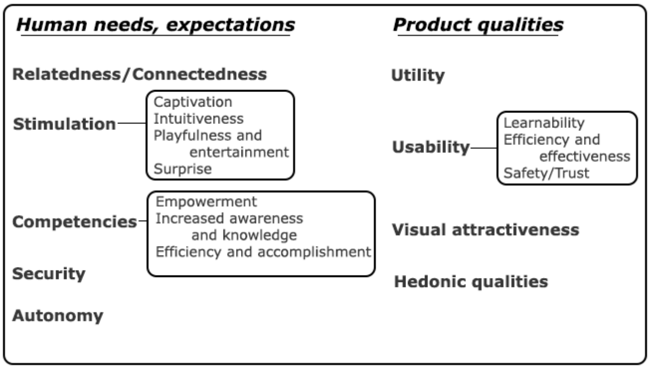

Figure 2. The UX evaluation framework used in this study

3.3. *UX framework*

The importance of User eXperience has been investigated and thoroughly established in the research community during the last fifteen years [12,13]. However, given the subjective nature of the topic, no standard framework has arisen as generally accepted by the community. Therefore, many of the frameworks proposed are specific to some research areas and tend to evaluate UX of a specific category of products. Although these frameworks differ for methodologies used, common traits can be identified. The most important of all is the categorisation of factors influencing the user experience of the product in two different categories: product qualities and human needs/expectations. The evaluation framework adopted in this paper strongly relies upon this subdivision, taking as model the framework proposed by Schulze and Kromer [14]. In their work Schulze and Kromer propose a framework for UX evaluation of online interactive products. The UX is the result of two influencing factors: basic human needs, such as relatedness, popularity or competency, and product qualities, such as usability or visual attractiveness.
Product qualities have been extensively studied. In [15], the most significant product quality measures are selected and commented. For what concerning human needs and expectation instead, the subjectivity of the matter imposes deeper investigation in the application context, in this case AR. Scarce consideration has been given to AR-related UX, and this is demonstrated by the absence of an evaluation framework specific to AR. Olsson et al. [10] identify meaningful components for the expected user experience of AR services. The influencing elements selected are mostly an operationalisation into an AR context of the basic human needs described by Schulze. The aforementioned frameworks were exploited to select a number of measures that this evaluation will consider. The resulting framework is shown in Figure 2.

3.4. *The experiment*

To evaluate the experience of GhostHands, a lab experiment was prepared. The setting consisted of 6 pairs of participants cooperating in pairs to perform a sequence of tasks. For each pair of participants, one of them impersonated the instructor, while the other was participating as trainee. The instructor was briefed before the experiment on the tasks to perform and the terminology to use to describe object. In order to simulate a factory-like scenario, the tasks were designed around piece of machinery currently used in industry that were replicated using cardboard. Three tasks of increasing complexity were designed to be performed in sequence with short rest intervals:

1. Rotor disc servicing: a rotor disc mounted on a shaft had to be rotated to compensate for wear and tear. (19 steps)
2. Motor/pump alignment: the pipe connecting motor and pump was misaligned and required realigning in order to prevent malfunction. (24 steps)
3. Thread feeder unit replacement: a very delicate piece of machinery that holds thin threads needed to be replaced through a complex and strict series of steps. (33 steps)

Each session, the two participants were separated by a barrier that prevented them to see each other. The trainee was equipped with headphones and a head-mounted camera, used to capture the video stream sent back to the expert. In front of him/her, the piece of machine to operate on was laying on a table. In background, a large screen showed to the trainee the video stream of what was being captured by the camera with the instructor's GhostHands superimposed. The instructor instead, was equipped with a laptop and the hands tracking sensor.
An open answer post-task questionnaire was presented to the participants after the experience. The questionnaire included questions about their experience and emotions regarding specific aspects of the experiment.

4. Results

As a general trend, the experience resulting from the experiment was of empowerment and safety. Trainees generally felt more self-confident knowing that an instructor was guiding them and teaching how to properly perform the task. This can also be partially caused by simply having the instructor guiding "over-the-shoulder", but some participants explicitly stated that GhostHands was particularly useful when the task was not obvious. "*It got me out of a few instances where I was stuck*". "*GhostHands allowed me to feel more 'safe' about the actions I was assigned to. As a learner I felt more empowered, since my confidence level was higher*". However, several participants that participated as instructors raised concerns about the precision of the application. During the gestures performance, the sensor can lose track of hands, especially if the user is not familiar with such a technology. That results in the hands model not accurately reproducing the gesture and the instructor needing to recalibrate the hands on the sensor. In the following sections findings will be presented with more detail.

4.1. Product qualities perception

All the participants found that this interaction modality generally sped up the instructions. "*Even though the tasks were relatively simple, I imagine it would have taken me more time to understand and carry out the tasks without the GhostHands*". Instructors perceived the interaction as natural and intuitive, using hands as if physically present in the trainee's space. For many of them being able to perform spatial gestures was greatly convenient. "*When struggling with or forgetting some name of the component, you just point at it. The same applies when you cannot find the proper verb or description*". However, the frequency with which instructors took advantage of the possibility to guide the trainee actively showing the proper movement to perform, was lower than expected. This is mostly due to the lack of confidence in using the sensor and the imprecision in hands tracking.

All the instructors considered that the situation in which hands were mistracked, affected negatively the experience. "*I would trust it if the imprecision is somehow addressed*". Also trainees in particular situations that required higher precision, considered wearing the camera somewhat uncomfortable. "*Unfortunately the precision of the instructions is heavily affected by the movements of the worker's head. He must be aware of that and avoid shaking his head*". In cases when instructors reached a confidence level high enough to perform gestures naturally, trainees felt safely guided through the task. "*GhostHands was as if I had a pair of expert hands taking mine and guiding me through the entire process*". Overall, both sides of the interaction experienced a significant improvement in perceived efficacy. Feedback on efficiency and effectiveness were extremely positive. "*When it comes to physical movements, written instructions and static pictures aren't very helpful and often misleading. Have you ever tried to follow origami instructions?*". Some participants, instructors in particular, suggested the integration with more visual information channels, such as arrows and shapes to improve pointing at small objects. For what concerning visual attractiveness, white plastic-like hands were considered suitable and "*appropriate for this industry-oriented tasks*". The majority of the participants were skeptical when asked if there was a possibility to improve the 3D hand model. In their opinion, models that look too realistic would feel uncanny, while it would be difficult to adapt to models that do not accurately represent human hands.

4.2. Human needs, expectations, visceral feelings

Feelings of empowerment and efficiency arise throughout participants' answers, as highlighted in Section 4.1. During the execution, instructors declared that operating with the tracking sensor became more and more playful and engaging as they mastered it. Occasionally they felt frustrated because of the poor tracking. "*I had great fun playing with the GhostHands and by the end of the experiment, I had started to feel confident. There were slight moments of frustration due to losing the GhostHands tracking/motion*". Except for the tracking issues, none of the users expressed negative feelings about the intuitiveness and naturalness of the interaction.

In some cases the playfulness of the interaction was also associated with the connection with the other side of the communication. The instructor congratulated the worker with a "thumbs-up" gesture, or they interacted with an "high five". "*I think it can help in improving team-work because it produces a sense of 'shared accomplishment'*". A certain number of concerns were expressed with reference to feelings of autonomy. The strong guidance provided by the instructor could interfere with the active learning process of the trainee. This can result in distraction and passive attitude towards the instructor. "*I felt that sometimes the worker may rely completely on the instructor being like a robot executing the instruction without really learning*".

5. Discussion

The aim of this work is to present GhostHands and evaluate this new interaction modality from a UX perspective. Users generally perceived the experience as greatly stimulating and with a strong sense of connectedness and playfulness, hence improving engagement. Instructors felt closer to their trainees while trainees felt safe and guided. This resulted in increased self-confidence and sense of empowerment, two feelings extremely important during the learning process. Results show how important is precision of the application for instructors. If the application fails, even only occasionally, at representing gestures and movements in real-time, hands models are perceived as uncanny. This produces a feeling of frustration that can discourage users from taking advantage of all the capabilities of such interaction. However, the major advantage of this cooperation channel lays in the naturalness and intuitiveness of the interface. Technology seemed to be completely transparent for users. All the participants learnt how to interact with the application in matter of seconds, and some mastered it in minutes, despite the fact that they were completely unfamiliar with the technology before the experiment. Therefore, one can assume that their capability to deal with the inaccuracies of the sensor will improve with learning.

All in all, GhostHands introduces a new channel of communication and learning perceived as natural and connecting, that can be integrated with the current AR-enabled interaction modalities to improve effectiveness and precision.

Our iteration in this research will focus on improving the stability and precision of tracking which is crucial for the final users. Concerns about effectiveness in learning will be addressed through a series of quantitative studies, and the development agenda also includes further application deployment for smartphones, tablets and smart glasses.

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Assessment of Task Engagement using Brain Computer Interface Technology

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Abstract. The electrical activity of the brain can be quantified by measuring the electroencephalogram (EEG), a technology that underpins emerging commercial Brain Computer Interface (BCI) devices. The EEG can be used to directly assess measures of brain function: sensory, motor and cognitive processes. In this paper we assess the readiness of this technology for application to teaching and learning. We propose a hybrid BCI methodology that can be used to gather EEG metrics during an immersive control task. The changes in EEG provide objective measures regarding user engagement with the task. When used in conjunction with eye tracking technology, a hybrid BCI offers the potential of exploring learning at a more granular level.

Keywords. Immersion, Task, Engagement, Brain Computer Interface, Eye gaze

1. Introduction

The Brain Computer Interface (BCI) is no longer considered as purely an assistive technology. With the advancements in electronics, wearable sensors, algorithms and software development kits there has been a shift towards exploring other applications that use 'thought processes' to interact with computing systems. BCI has gained interest within gaming [1], assessing creativity [2] and as a non-invasive physiological observation mechanism [3].

In terms of mental state, certain characteristics within the ongoing electrical activity of the brain, known as the electroencephalogram (EEG), can be derived which provide insight into the ongoing sensory, motor and cognitive processes. Features that determine levels of engagement may be measured and quantified. These are based on derived EEG components, such as theta and alpha waves which are diffusely distributed across the scalp. In the future with appropriate technology it may be possible to investigate more subtle location specific cognitive processes, whilst a user is actively learning. Of course researchers in the field of neuropsychology have been active in this pursuit for many decades. However, over the last few years, devices have become widely available that record this activity away from the dedicated neurophysiology laboratory, allowing for a more pervasive solution. In addition software applications can provide feedback in real-time, allowing the effects of sensory

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stimulation to be assessed in an interactive manner, and facilitating the user to become more actively involved in the paradigm.

In this paper we assess the possibility of using a commercial BCI to provide an objective measure of task engagement. The research is at an early stage. If engagement can be measured, then this could be an initial step towards assessing whether a person is actively involved with a learning paradigm. Indeed it can potentially allow known conditions such as dyslexia to be quantified and alternative learning strategies to be investigated. The remainder of the paper is structured as follows. Section 2 reviews this emerging technology to support an immersive environment. It proposes that engagement can be enhanced by combining an EEG headset with eye tracking technology. Thus we can assess 'where' the person is looking and if this is having an effect on the EEG. Section 3 defines the concept of engagement and evaluates previous work on EEG components that could objectively measure engagement. Section 4 details a preliminary experiment, which shows that EEG can be used to differentially classify 4 navigation tasks, which the user must actively engage with. Section 5 concludes with a discussion of the possibility of using this technology in an education scenario.

2. Advances in BCI and Eye Tracking Technology

Commercial BCI is increasingly targeting health and wellbeing applications, such as brain training, cognitive state monitors and digital entertainment controllers [4]. Vendors such as Emotiv (EPOC), Neurosky, Advanced Brain Monitoring (B-Alert X10), Interaxon (Muse) and Melon provide "lifestyle" BCI systems that employ headsets and headbands designed for ease-of-use and comfort. Dry and water based electrodes have been introduced to promote user acceptance. The technology has been designed with portability in mind, using wireless communication protocols, linked to laptops, tablets and smart phones. Additional sensor technologies such as accelerometer and gyroscope can provide contextual information on movement and orientation. Other channels such as electrocardiogram (ECG), electromyogram (EMG), electro-occulogram (EOG) and eye gaze may also be recorded, providing the possibility of a 'hybrid' BCI. On the downside, this emerging technology is restricted in the number of recording positions (4-14 electrodes) by comparison with laboratory systems (typically 16-32 electrode positions). Vendors have also provided psychophysiological assessment using proprietary signal analysis, yielding ab array of user behaviour metrics such as 'focus', 'engagement', 'interest', 'excitement', 'stress', 'confusion' and 'fatigue'. For example, the Melon headband measures brainwave activity at the front of the scalp, and claims to facilitate the detection and analysis of mental states including 'focus' and 'meditative states'.

Eye tracking is useful technology to assess task engagement. Until recently it has been expensive and restricted to dedicated laboratories. However this is changing; vendors such as Eyetribe have introduced a low cost, portable device with an Application Programming Interface (API) that facilitates integration with BCI to provide a hybrid BCI system where eye tracker and BCI can be used in a collaborative fashion.

3. User Engagement in an Immersive Environment

In order to address the effectiveness of any immersive environment, it is desirable to measure the level of engagement that a subject has with computer-generated content being played. Conventional objective measurement approaches involving visual (e.g. eye tracking) or aural sensing (e.g. speech analysis) do not necessarily indicate fully objective engagement with the user's thought and reasoning processes. Self-report data in the form of a questionnaire may be used but these data are subjective.

Engagement comprises the "perception-cognition-action-experience"; it refers to sustained involvement with an activity. Peters et al. [5] state that many overlapping user states are termed as engagement: interest, sustained attention, immersion and involvement. They suggest that a key factor in promoting engagement is the design and implementation of intelligent interfaces that can adapt to both the user and context. They further partition engagement as attentional and emotional involvement, leading to affective involvement.

States of extreme engagement, as in gaming for example, have been described: bored, apathetic, in-flow or anxious. Transitions between states occur as the balance between task demand and the user's skills change (this is why games need different levels of challenge). Task engagement can be defined with respect to cognitive activity (mental effort), motivational orientation (approach versus avoidance) and affective changes (positive versus negative valence) [6]. The engagement cycle, as defined by O'Brien and Tom [7], consists of four phases: point of engagement, sustained engagement, disengagement, and re-engagement. They propose the following definition: *"Engagement is a category of user experience characterized by attributes of challenge, positive affect, endurability, aesthetic and sensory appeal, attention, feedback, variety/novelty, inter- activity, and perceived user control".*

Hence an effective computer mediated task must comprise feedback, user control, attention, motivation and the ability to challenge individuals at levels appropriate to their knowledge and skills. Engagement has also been described as the first in three levels of immersion. A mechanism that has been previously considered as a measure for engagement is 'where' the user is looking on the screen in correlation with certain times. Additional useful information may be derived from user attributes such as head direction, blinking, body movement and gestures. EEG can provide a direct channel to the brain's sensory and cognitive processing, providing a direct channel to measure engagement. This provides a further area of investigation, particularly with the deployment of appropriate low cost technology.

3.1. EEG for Measuring Engagement

In terms of measuring engagement as a cognitive process, EEG and other physiological signals may offer insight. According to Fairclough et al [6]: *"Physiological computing describes a category of technological systems that capture psychophysiological changes in the user in order to enable and inform real-time software adaptation."*

To evaluate suitable mechanisms for extracting such useful information, it is important to understand how physiological signals, such as EEG, can be used to determine a measure of engagement. The role of EEG in determining levels of alertness, attention and cognitive tasks, suggests that measuring brain activity can form a valuable input to such a system [8]. Using EEG, alone or combined with other sensor inputs, it is possible to evaluate the degree of engagement or immersion that a user has with different types of digital content. The content can potentially be updated in reaction to the user's response. Table 1 gives an overview of the 'classic' frequency bands within the EEG, i.e. the rhythms, which can signify certain characteristics.

Gevins et al. [9], [10], used theta activity from central frontal sites combined with suppression of alpha activity from occipital areas to indicate an increase in mental workload with an emphasis on remembering information. Davidson et al. [11] investigated frontal asymmetry as a potential metric, on the basis that positive emotions relate to high levels of left frontal activity and negative emotions are associated with higher activity in the right frontal location. Fairclough et al. [6] investigated frontal asymmetry combined this with frontal theta activity and cardiovascular response, namely, systolic blood pressure.

Table 1. Frequency Bands of the EEG

Rhythm	Freq (Hz)	Amp (μV)	Description
Delta	1-5	20-200	Present during deep sleep but may also increase during mental activities requiring concentration.
Theta	4-8	10	Present during sleep but may also occur at times when subject is frustrated, daydreaming or performing automatic tasks. In general, the occurrence and amplitudes of delta and theta rhythms are highly variable within and between individuals.
Alpha	8-13	20-200	Prominent wave pattern of an adult who is awake but relaxed typically with eyes closed although some subjects can use relaxation techniques to maintain the signal amplitude while eyes open. Greatest amplitude from the occipital areas but also from the parietal and frontal regions of the cerebral cortex.
Beta	13-32	5-10	Present when subjects are alert with attention to external stimuli, or engaged in a mental task. Recorded from the parietal and frontal lobes. Lower in amplitude than alpha waves
Gamma	32-100	5-10	Observed as neural synchrony from visual cues (both conscious and subliminal). The waves are link to consciousness and may relate to perception. They may be enhanced by meditation. The waves are prominent at 40Hz and may be linked to sensory processing in the visual cortex.

3.2. Examples of the use of BCI systems and EEG for self-quantification

Aspinall et al. [3] used a consumer-grade BCI headset, specifically the Emotiv EPOC, to monitor the effect of the surrounding environment on the mental states of their subjects. They asked subjects to walk through different areas of Edinburgh, which had been categorized as urban shopping streets, a green space, and a busy commercial district. From their recordings they looked for periods of excitement, frustration, engagement and meditation.

Crowley et al. [12] evaluated the use of Neurosky's Mindset headset to measure the attention and meditation levels of a subject. They found that the device provided information about the user's change in emotions. Szafir et al. [8] presented a system with an adaptive agent; and with the goal of monitoring and improving engagement. They also used the Mindset headset, gathering recordings from 4 electrodes. Reinecke et al. [13] analysed the EEG in the alpha, beta, theta, and gamma bands. Their results reinforced the capability of EEG as a suitable measure of user engagement and mental state, applied to sports science.

Zander et al. used of passive BCI; in [14] they suggest that passive BCI could be used to enable a greater understanding of important contextual information during mental tasks. Similarly, it has been proposed that electrophysiological patterns associated with specific cognitive processes, such as concentration, may be identified and explored using BCI technologies [15]. Rebolledo-Mendez [16] used the Mindset to investigate alpha wave activity for meditative states; they compared these with self-reported attention levels.

A series of experiments demonstrated that augmentation of theta activity (4–7 Hz) from central frontal sites and suppression of alpha activity from occipital areas were both associated with increased mental effort in response to working memory load (i.e. number of items to be retained in memory) [9] [10]. In addition, Andujar et al. [17] [18] focused on improving subjects' experience during a reading task using the EPOC. They established a baseline for engagement and when the signal values dropped beneath this level they improved engagement by showing snippets of videos. They use a simple ratio devised by Pope [19] to give a measure of enagement from alpha, beta and theta bands:

$$Engagement = beta \quad alpha + theta \tag{1}$$

Goldberg [20] devised an Intelligent Tutoring Systems using outputs from Emotiv's Affectiv Suite; short-term excitement, long-term excitement, and engagement. Overall, this study supported the use of the Emotiv as a low-cost solution to model cognitive state for desktop training applications. Roe at al. [21] also employ Emotiv's Affective Suite, using excitement, frustration, engagement, long-term excitement, and meditation measures to evaluate a subject's response to natural versus urban settings.

4. Experimental Methodology and Results of a Pilot Study

How useful could the information obtained from these devices be for measuring engagement? A pilot study was conducted, which evaluated a consumer-grade BCI device, the Emotiv EPOC, in order to engage subjects in an immersive task.

4.1. Methodology

Four healthy participants (age range 22-56, 3 male and 1 female, all with prior BCI experience) took part in a short recording session that lasted approximately 30 minutes inclusive of setup and data acquisition. The Emotiv EPOC was cleaned with a 50% diluted solution of white vinegar and a soft cloth. The rear of each sensor was gently agitated with this solution to remove any corrosion. Before each trial, all electrodes and felt pads were placed in a hydrator pack and a saline solution applied. After this, each electrode was secured to the device and positioned appropriately on the head of the participant.

At the beginning of the session, the participant was required to undergo a training procedure facilitated by the Cognitiv Suite, which employs various approaches such as EEG and electrooculography (EOG). It records and interprets a user's conscious EEG and intent so as to enable the user to manipulate virtual objects. The Cognitiv Suite was used to train a ‘neutral’ state plus four navigation commands; left, right, lift, and drop. When training the neutral state the participants were required to relax and clear their thoughts. To train the left and right commands, the participants were asked to focus their gaze on markers to the left and right of the screen. To train the lift command, the participants were required to clench their teeth, and to train the drop command the participants were asked to tap their left foot.

Each trial commenced only after the individual participant had trained each command to an accuracy of greater than 70% (as advised by the Emotiv software). For all participants, each command had 3-15 training periods, with each training period lasting 8 seconds. Once the session began, the participant was issued with twenty requests (e.g. move a virtual object in one of four directions) and allowed ten seconds to complete each request. A five second rest period was given between each request in which the participant was asked to relax in order to simulate the neutral state. For each request the participant had to concentrate on moving an object to one of four locations on the screen; top, bottom, left, or right.

4.2. Results

Including the training phase, each session took no longer than 30 minutes to complete. The easy to use interface with real-time feedback on the status of the electrodes also improves usability. The EEG time activity for each channel and spectral bands may also be viewed in real-time. Within this study, it was established that the use of a consumer-grade BCI headset (and accompanying software) for manipulating a virtual object based on gaze direction and actual movement is possible. These results suggest that the quality of EEG recorded using the EPOC is of an acceptable level for such tasks.

Over the initial training phase all four participants acquired a reported skill level greater than 70% for each command, as shown in Table 2, which also defines the skill rating of each individual command for all participants. From Table 3 it can be observed that each participant exceeded the 20% accuracy expected by chance. The mean accuracy for all participants equates to 64%, with participant B and participant C performing greater than 85%. Each of the four commands was issued five times per participant in a random order. All participants were able to correctly complete the lift command 100% of the time, the right command 55% of the time and the left and drop commands 50% of the time.

Table 2. Training skill rating as reported by the Cognitiv suite

Subject	Gender	Overall Skill Rating	Left	Right	Lift	Drop
A	M	83%	86%	94%	76%	76%
B	M	79%	77%	71%	91%	78%
C	M	81%	74%	83%	87%	80%
D	F	81%	80%	95%	71%	78%
Mean		81%	79%	86%	81%	78%

In addition, Table 3 represents the actual accuracy and defines the number of each request that was completed correctly.

Table 3. Subject accuracy achieved for each subject for each request

Subject	Gender	Actual Accuracy	Left	Right	Lift	Drop
A	M	35%	1	1	5	0
B	M	85%	4	3	5	5
C	M	90%	5	3	5	5
D	F	45%	0	4	5	0
Total		64%	10	11	20	10

Within this study, it is evident that reasonable control can be achieved with little training. Nevertheless, there are number of previous studies that suggest that the performance of the EPOC is lower than that of a research-grade BCI [22]. All participants had experience of research-grade devices and stated that the EPOC was much more comfortable and less difficult to setup. Furthermore, all participants agreed that, as with any BCI device, prolonged use causes fatigue. However, this study demonstrates that specific users are able to gain reasonable control with little effort, though suggests that this will not be the case for all users.

5. Discussion

The data presented in this paper shows that it is possible to interact with an immersive environment using a BCI headset alone. Albeit, we must be cautious due to the small sample size (N=4). However, this is not sufficient to study the active learning process. A further challenge is to analyze the EEG activity for robust measures of engagement using metrics such as suggested in Equation 1. To date, we have utilized purposely created classification algorithms, and these show some promise. Whilst engaged in a learning task, the EEG activity will include artifact due to eye movement and muscle activity. For a BCI to have merit in an education environment 'cognitive features' must be able to compensate for this or we may well be recording reading (ocular movement) without comprehension, for example.

An important educational 'use case' could be the automated assessment of engagement for children with special educational needs, such as sensory impairments, dyslexia, autism, etc. Part of this could be the assessment of comprehension and assimilation of information provided to the subject. Assuming that a robust measure can be derived from this engagement task, it may be possible to further address specific tasks such as reading. This could be valuable for understanding learning and the lack of educational progress associated with these conditions. Andujar and Gilbert [17] have used a BCI approach to investigate 'physiological reading'; in this innovative reading approach the reader's learning experience is enhanced by displaying engaging videos related to the reading when the engagement metric drops under an EEG determined baseline. In further work we have combined commercial devices (EPOC and Eye Tribe Eye Tracker) to achieve better control and interactivity with a virtual environment. This hybrid BCI has the potential to provide a finer grained environment for investigating engagement as we will be able to determine the link between where the person is looking and EEG measures of engagement.

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Towards Measuring Learning Effectiveness considering Presence, Engagement and Immersion in a Mixed and Augmented Reality Learning Environment

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Abstract. The current era of advanced display technologies, such as a head mounted displays, smart glasses and handheld devices, have supported the usage of mixed-reality and augmented reality concepts in smart educational classrooms. These advanced technologies have enabled enhanced collaboration and an interactive communication between distance learners and local learners. Being present' is a key factor in both worlds (real and virtual) as it plays an important role in increasing the students' collaborative engagement during the learning activity. However, few studies have considered how much using such immersive interfaces with various learning scenarios may ultimately affect learning outcomes, and whether students feel fully engaged or not in such environments. This work-in-progress paper will demonstrate a MiRTLE+ prototype of how remote students can collaborate within mixed-reality environments by using an augmented reality approach. Secondly, it will explore the learning effectiveness based on the following factors: students' presence, engagement, and immersion in smart environments. With regard to the learning task, we will consider a card game task to measure the learners' progress as they progress from novice to expert player. To evaluate these factors, we utilise several existing frameworks which have been applied to our mixed-reality worlds that help us to examine the learning outcomes from using these environments.

Keywords. Presence, engagement, immersion, augmented reality, mixed reality, learning effectiveness, smart classrooms, group learning, turn-taking technique.

1. Introduction

Advances in 3D virtual environments and the use of other equipment such as head mounted displays, goggles and new smartphones can provide new opportunities for teaching and learning. These new environments can potentially lessen the sense of isolation of distant learners [1] and allow students to communicate in a more natural way with a greater sense of "being there".

Some recent studies [2][3] have used mixed-reality concepts to achieve interactive communication amongst remote and local people in 3D virtual-reality environments (VE). For example, Gardner and O'Driscoll [4] and Schmidt et al. [5] found that

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representing remote students as avatars on a screen in a real smart classroom could enhance the remote students' sense of engagement and increase their feeling of 'being there' (through virtual connections to their real teacher and fellow students). On the other side, concerning platforms and immersive interfaces in teaching environments, newly announced technology innovations, such as Microsoft's Hololens [6] provide the prospect that, within the next few years, there will be affordable platforms available for education what will make the realisation of the hologram-style vision described later in this paper a realistic prospect.

However, users of virtual environments have usually very limited interactions with their real teaching environments and people within it. Our research is firstly focusing on developing the MiRTLE system in order to increase the interactivity between remote virtual and 'real' students in the teaching environment using augmented reality technologies. So far, however, there has been little done to increase the interactivity of remote virtual students in physical smart spaces based on the dynamics of interconnecting physical objects and people with their virtual counterparts using augmented reality technologies and various immersive interfaces. In this respect, we are also investigating the learning effectiveness considering the students sense of presence, engagement and immersion factors in such learning environments.

In the remainder of this paper, we discuss this further, in four parts. The first part describes the background and related work. In the second part, various learning scenarios and the system architecture of our research experiment are presented. The third part will demonstrate the experimental approach which includes our MiRTLE+ prototype, test bed and research challenges. Finally, conclusions arising from this approach and future work are discussed.

2. Background and Related Work

2.1. Mixed Reality

Previous work has demonstrated how a mixed reality approach can be used as an advanced tele-presence method, which connects a virtual environment with a physical environment [7]. With regard to the Reality-Virtuality Continuum as shown in Figure 1, mixed-reality has been divided into two components: Augmented Reality and Augmented Virtuality, where the world is mostly real, or virtual (computer-generated), respectively, with the two extremes at either end of the Mixed Reality continuum correspondingly being reality and virtuality (i.e. where the world is 100 per cent real or computer-generated). As a result, [8] observed that "*the most straightforward way to view a mixed reality environment, therefore, is one in which real world and virtual world objects are presented together within a single display, that is, anywhere between the extreme of the Virtuality Continuum*" [8]. The Mixed Reality Teaching and Learning Environment (MiRTLE), from the University of Essex [9], and the Holodeck system from the University of Hawaii [5] are examples of mixed-reality learning environments.

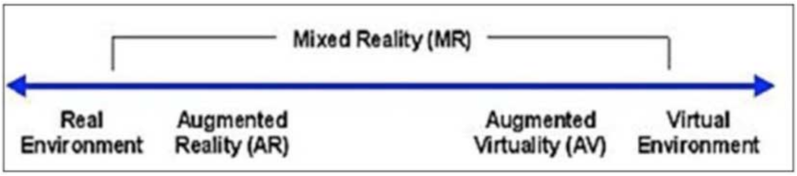

Figure 1. Milgram's Reality-Virtuality Continuum [8].

2.1.1. MiRTLE

MiRTLE has been deployed in the iClassroom, which is a high-tech teaching environment at the University of Essex. It consists of speakers, microphones, and a voice-bridge (in the system) to enable voice communications between remote and local students. Furthermore, the iClassroom also includes an Internet camera and a large display screen, which are both MiRTLE components. Thus, physical students can be viewed in the virtual world screen through the use of the camera, which is mounted on the iClassroom's back wall. The virtual students are displayed in the real environment through the screen positioned at the rear of the iClassroom. This screen allows the teacher and real students in the iClassroom to see virtual students in the lecture as shown in Figure 2.

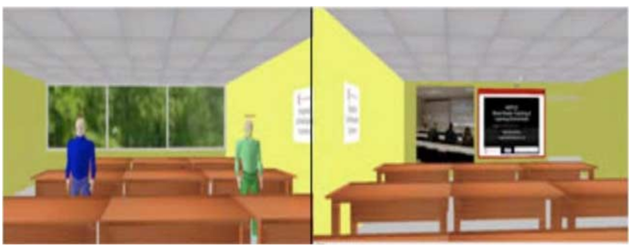

Figure 2. Lecturer's View of Remote Students (left) and Remote Students' View of the Lecture (right)[4].

Moreover, the remote student's avatar can be viewed on the screen based on the user's preferences [7][9]. Therefore, the virtual student's presence in the real world is screen-based, which can be seen as a limitation in terms of having more interactive communication with real students in the physical classroom.

2.2. Augmented Reality

The Augmented Reality (AR) term was defined by Caudell and Mizell [10]. AR is used in the real-world (physical) environment where elements are augmented by computer-generated sensory input such as sound, video, graphics or GPS data. It relates to the more general concept called mediated reality in which a view of reality is modified by a computer [11]. AR systems generally consists of three key points [12][13]:

- Binding real and virtual objects in a real environment.
- Registering real and virtual objects with each other.
- Making the use of 3D and 2D objects in a real environment.

Recently, engineers at Microsoft have developed a fully immersive augmented reality headset called the Hololens [6]. It is a computer headset that enables the projection of hologram-style images within the real world, which is different to technologies such as the Oculus Rift that present a fully immersive virtual environment around the user [14]. In our study we plan to investigate the use of these technologies from a pedagogical perspective. We also plan to determine the learning affordances of such augmented and mixed reality devices.

For educational purposes, the use of AR promises new opportunities for fostering a greater sense of engagement and motivation amongst students. For instance, an AR based game called “Learning Words”, which uses a head mounted display (HMD) device, was developed and tested among 32 pupils. The results indicates that more than 80 % of the audience preferred AR systems over conventional systems for learning [15].

Our study plans to more deeply investigate the impact of using different user interfaces in a mixed and augmented reality space particularly for increasing the sense of presence and engagement of the users. Moreover, it will examine other factors that may affect the users sense of presence and engagement in these spaces, such as the choice of learning tasks being carried out in collaborative learning groups.

Several factors can contribute to measuring the sense of presence in a VE based on the users sense of ‘immersion’ and ‘involvement’ in the task.. These factors include control, sensory, realism, and distraction factors as shown on Table 1. These factors can be used to help form the content of subjective questionnaires for measuring the users sense of presence. Some studies [16][17][18] have applied these factors to measure presence and other emotional and subjective feelings. Also, these studies have already shown their validity for generating questionnaires for measuring these factors in 3D mixed and virtual environments. In our study we plan to consider some of these factors to help us generate questionnaires in order to measure the users sense of presence and immersion in a range of collaborative learning tasks.

Table 1. Factors hypothesised to contribute to a sense of presence [17]

Control Factors	Sensory Factors	Distraction Factors	Realism Factors
Degree of control	Sensory modality	Isolation	Scene realism
Immediacy of control	Environmental richness	Selective attention	Information consistent with objective world
Anticipation of events	Multimodal presentation	Interface awareness	Meaningfulness of experience
Mode of control	Consistency of multimodal information		Separation anxiety/disorientation
Physical environment modifiability	Degree of movement perception		

3. MiRTLE+

Our ongoing research project is based on the original MiRTLE concept [1]. However, we plan to extend this approach to investigate more interactive and engaging techniques for merging local and remote learners within a real classroom setting. By using augmented and mixed reality concepts within MiRTLE, we plan to bring remote students (by using their virtual representation), more closely together with their local (physically present) students. We hope that this approach will enrich the learning activities within the mixed-reality learning environment and will particularly improve the collaboration and sharing between local and remote learners. We refer to this new system as MiRTLE+.

3.1. Learning Scenario

Alrashidi et al. [19] proposed a 4D learning activity framework that structures learning activities from simple single learner discrete tasks to more complex group learning sequenced tasks. We are using this framework to define the scope of learning tasks being considered for MiRTLE+. Thus, in our learning activity scenario, we focus on group learning with multiple sequenced task. Typically in our scenario this involves four students, two local and two distant, who work together to achieve the learning tasks being undertaken.

We propose a simple learning activity task where a group of students are asked to play a card game, which will have a number of rules and instructions. Usually, people prefer to learn these types of games by being able to practice with experts whilst playing a real game. Thus, we will be using a ‘learning by doing’ approach. We plan to apply this approach to our learning activity by splitting the group into two expert and two novice students. This will hopefully help the novice learners who do not have any previous background or knowledge of playing the card game to practice and play with their expert peers.

Moreover, as the group working together, turn-taking coding approach will be considered as a key factor in our study to allow equal rights between members, since there is no teacher to decide who plays next and when. Thus, the software will enforce the turn-taking and controlled play, and however the expert from each team may also take over the turn once the novices need.

By mixing the group, the novice learners will start learning the game concepts by questioning experts, and discussing the rules before playing the game for real. We plan to examine the effect of mixing the novice and expert pairs across the different real and virtual spaces to explore how the virtual and real world dynamics affect the performance of the collaboration and the learning outcomes achieved.

3.2. System Architecture

The MiRTLE+ architecture extends the approach already developed by the original MiRTLE system to more closely involve remote students in live classroom teaching sessions. It particularly aims to develop this work by more closely involving remote (virtual) learners in the real classroom by using new approaches based on augmented reality and the use of head-mounted immersive displays. The main focus for integrating the real and virtual students is the development of a virtual classroom that synchronises the activity that is taking place in the real and virtual settings. Figure 3 shows the main view layers and components in both the virtual and real classroom. All of these components are mirrored in both classrooms, as discussed in the following sub-sections.

1) *User interfaces layer:* this uses several augmented and mixed reality displays such as traditional PC screens, handheld displays, AR glasses and MR glasses. The learner can use these displays as a means to communicate between the different learning environments. We anticipate that this will support the following learning affordances:
    1. Visualising remote learners in a real environment – enhanced collaboration.
    2. Supporting richer problem solving learning activities.

3. Supporting seamless voice communication between the participants.
4. Providing real-time feedback on the learning activity.
5. Allow for greater interaction with the objects being used.

2) *Real environment layer:* this is where the local learners attend. For this we are using the iClassroom at the university of Essex [20]. This iClassroom consists of smart objects such as a meeting table, tablets, smart windows, light sensors, air-conditioning and chairs. These smart objects have virtual representations in the virtual world. In addition, each local learner will have a virtual representation in the virtual world. The remote students will also be displayed within the real environment as an avatar using augmented reality. Thus, this layer utilise a marker-based augmented reality approach to combine both local and remote students within a real classroom.

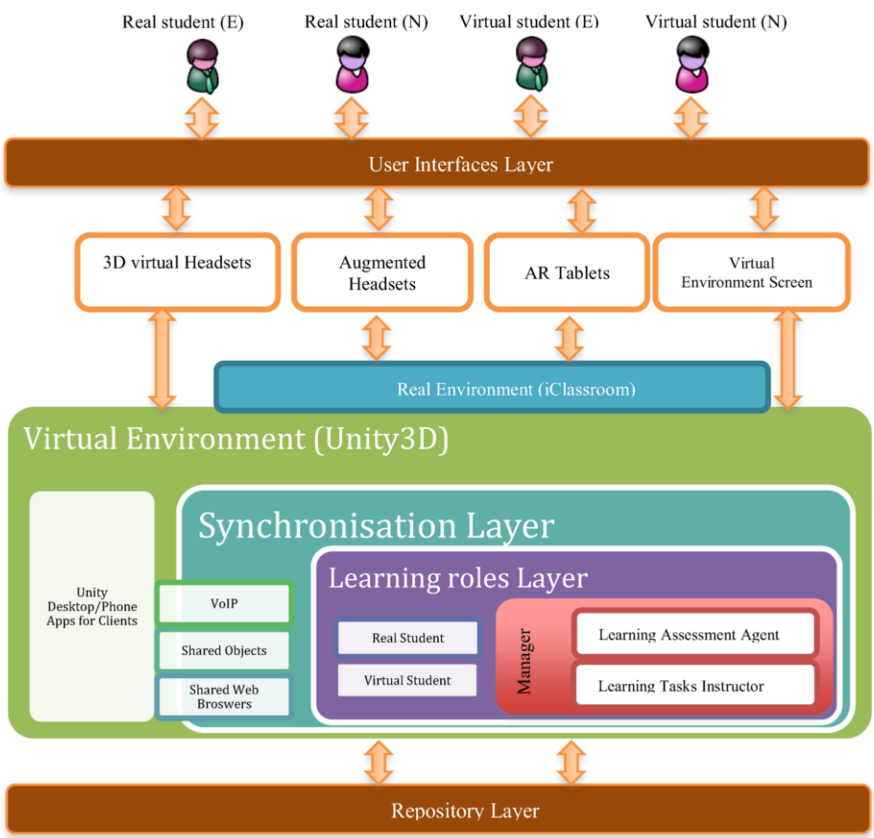

Figure 3. System architecture.

3) *3D Virtual environment layer:* Is where the remote learners meet the local learners in a virtual classroom. Both local and distant learners are presented each as an avatar within the 3D virtual environment. This virtual classroom is identical to the iClassroom in terms of the objects within it and its shape. This

layer provides the view for the distant learner as a means to collaborate with their peers in the real environment.

4) *Synchronisation layer:* Manages the interactions and communications between both worlds in real time. Any changes that occur in the real or virtual world should be notified and updated to both worlds. The main components, which the system keeps track of, are as follows:
   a. *Voice component:* Is responsible for delivering multi-party voice communication over the network. It allows distant learners to use voice communication to discuss and interact with their local learners
   b. *Shared objects component:* Contains all the materials required for the learning activity: such as screens, chairs and tables. For example, the remote (virtual) student, whose avatar will be 'sitting down' on a remote virtual chair, can be viewed as an augmented avatar in the same chair in the real environment. At the same time, the real student can choose to sit down on the available (not already occupied by a virtual student) chair in the real environment.
   c. *Shared web browsers component:* This is responsible for providing the shared content and learning instructions for real and virtual students and allows the students to collaborate together on the learning activities in both the real and virtual iClassroom environments.
5) *Learning Design layer:* Defines the role of the learners (local and distant), and the specification of the learning activity, and the assessment and feedback strategies that will be used.
   a. *Real students component:* Allows the usage of augmented reality tools and physical smart boards, objects (chairs, table and tags) and a physical screen for displaying shared content in the real world.
   b. *Virtual students component:* Allows the usage of all 3D virtual objects (i.e. web browsers textures, chairs, table and voice) in the virtual world.
   c. *Learning content:* Provides students with the instructions and learning content to begin and achieve the learning tasks. It's main objective is also to support and guide the students as they work through the tasks.
   d. *Learning assessment component:* Is responsible for monitoring the students performance and providing feedback.
6) *Repository layer:* Is responsible for communicating with the server and clients in order to store and retrieve the users' roles and profiles, environment settings, and learning content and feedback.

4. Experimental Approach

Based on the learning activity scenario proposed (see section 3.1), we have divided our group into four possible scenarios. This division is based on two factors; the students' location (real or virtual world) and their level of expertise (expert (E) or novice (N)).

This will be used to determine whether their location (in the real or virtual space) has an affect on the learning outcomes and their overall performance. The following figure 4 illustrates these scenarios.

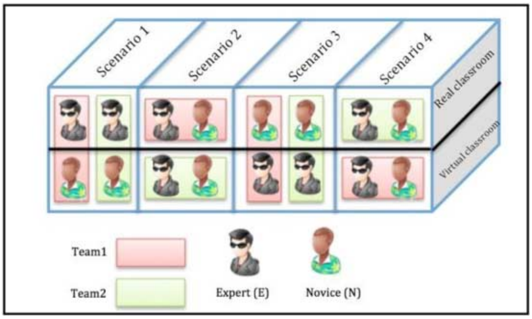

Figure 4. Structure of the learning scenarios.

The learning activity will have 4 players, with two teams of 2 players. In the first scenario, each team will have an E and N player. The E of each team will play from the real environment, and the N of each team will play from the virtual environment. In the second scenario, the distribution of players based on their levels is the same as in the scenario 1. However, the team 1, which consists of E and N player, who will play from the real environment and the team 2 will play from virtual environment. The third scenario is the opposite of the scenario 1 in terms of the students' locations, and therefore the E of each team will play from the virtual environment, and the N of each team will play from the real environment. The scenario 4 is also the opposite of scenario 2, and therefore the team 1 will play from the virtual environment and the team 2 will play from the real environment. However, the groups will go through two phases:

1. Phase 1 (using tablets for real learners and VW screens for the remote learners).
2. Phase 2 (using an AR headset for the real learners and an Oculus Rift headset for the remote learners).

4.1. Research Questions

We proposed the four scenarios and both phases to answer the following research questions:

1. Is there any difference in the students' sense of presence, engagement and immersion depending on which of the learning platforms they are using (i.e. real or virtual)?
2. Is there any difference in the students' learning effectiveness depending on which of the two platforms being used?
3. Are students more immersed and engaged in the phase 2 than phase 1?
4. Is there any difference in students' learning effectiveness relying on the phase 1 and phase 2?
5. Is there any difference in the students' sense of presence, engagement and immersion depending on the learning scenario/activity being used?
6. Is there any difference in the students' learning effectiveness depending on the learning scenario/activity being used?

4.2. Technical Implementation

Our initial implementation of the MiRTLE+ prototype is illustrated in Figure 5 and 6, for a local (female) student and a remote (male) student, respectively. The female student will have entered the real iClassroom and logged in to the virtual environment using a tablet interface. Then using the augmented reality interface she will have seen on the left chair that her virtual colleague was already sitting down (with a red t-shirt as shown in Figure 5). While she can see his avatar and communicate with him (via the tablet), the male student on the other side (virtually) can see her as an avatar and communicate with her using his microphone.

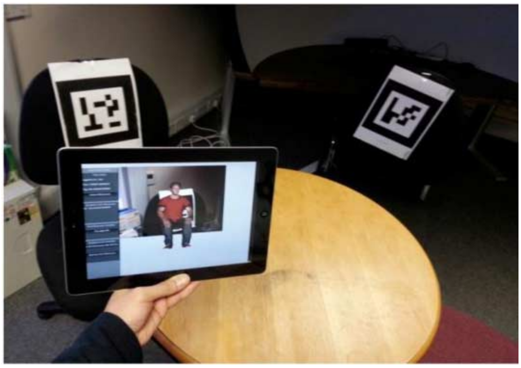

Figure 5. A screenshot during real user communication with the virtual user as an augmented reality avatar, using their iPad.

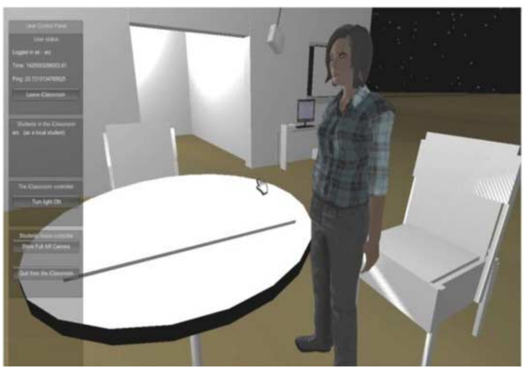

Figure 6. A screenshot during the virtual user communication with the real user (via her avatar), using his PC.

In our first phase prototype, we have developed two collaborative learning platforms. First, we have developed an Augmented Reality Collaborative Application (ARCA) to be used within the real iClassroom to allow local students to communicate with the remote students. This ARCA is based on our system architecture as shown in figure 4. This AR based platform was developed with the Unity3D game engine [21] by using the Metaio Augmented Reality Software Development Kit [22].

In the second phase platform, we have developed a 3D virtual environment where all the students are visualised. This environment is similar to the first platform (ARCA) in terms of shape and components. We have used the SketchUp [23] modeling software and Unity3D environment in order to build this VR-based platform. This platform consists of chairs, table, boards speakers, web browsers, lights and avatars. Furthermore, we have developed the voice communication interface by using the

DFVoice package [24], and a shared web browser by using the uWebKit package [25]. Both packages are integrated within the Unity3D environment.

The aim is to synchronise all activity in both the real and virtual worlds. To do this we have used a SmartFoxServer [26] server. This also integrates with the real iClassroom web services in order to communicate with its intelligent components (i.e. lights, sensors, air-conditioning system and electronic window) and synchronise them with the virtual world.

4.3. The iClassroom Test Bed

We use the iClassroom for our learning activity as a test bed. Figure 7 shows two environments; the iClassroom on the left side, and the simulated 3D virtual environment on the right side. The real iClassroom as well as the simulated 3D space (virtual iClassroom) have the following components:

- A table.
- Four chairs.
- Markers on chairs.
- Two iPads in the real iClassroom.
- Smart boards.
- Two Web browsers in the virtual environment.
- A PC on the real table.

Figure 7. The real iClassroom (left) and the simulated virtual iClassroom (right).

The local students will enter the iClassroom and log into the virtual iClassroom using their tablet. At the same time, the remote students will log into the virtual environment using their personal computer (laptop or PC). Once both learners (local and distant) are logged in, then they can go to the discussion table. Here, the system will give the learners the choice of their preferred seat. The local learner can check the availability of the seat by pointing their tablet's camera at the marker that is placed on the chairs. If the local learners see an avatar overlay on top of the marker that will mean that this chair is already reserved (see figure 5), otherwise the learner can see a text overlay asking them to confirm their choice for sitting on the chair. The local learners interact, communicate and discuss with the virtual learners by pointing their device camera at the chairs to see their avatar as an overlay on the real world. This is the first phase of our experiment.

In addition, the second phase, which is still under development, will enable both local and remote students to use immersive headsets and they will follow the same scenario as in phase 1. This will allow us to explore whether the level of immersion (provided by the end user device) will have an effect on the performance of the session.

The real and virtual learners can look at the learning activity task by using a shared electronic board; this will include information on the learning instructions, objectives and assessment being used. Once the students are familiar with the learning activity and their roles, then they can start the learning activity. In each above-mentioned scenario, the novice of each team starts to discuss the rules of the card game with the expert using either the voice or chat interfaces. They also play and discuss their achievements using the smart board in the real iClassroom and virtual iClassroom. The real smart board is synchronously connected with the virtual one, so that both worlds share the same web-resource.

4.4. Evaluation Design

We will use 6 groups of students who play in both phases. Each group will have four students: two are experts in playing cards, and two are novices. The participants will complete a basic pre-test in order to allocate their roles in the game.

Our study will follow between-subjects design. Thus, the groups will be distributed based on our learning scenarios (see section 3.1), and our control groups are: all players in the real world and all players in the virtual world. Therefore, our independent variables are based on the students expertise (experts and novices), students locations (real and virtual environment) and students interfaces (phase 1 and phase 2).

To evaluate our experiment, participants in each group will also be given an electronic pre-survey questionnaire in order to test their knowledge in playing cards as well as the use of augmented and mixed reality technologies. Subjective post-survey questionnaires including presence, engagement, and immersion measurements will also be given to the participants after they finish the learning activities. An example question used for measuring the users sense of presence which is derived from the work of Witmer and Singer [17] that specifically focuses on the ‘involvement’ factor is presented in table 3.

Table 3. Questions in the ‘involvement’ category [17]

Please rate your experience for each question on scale of 1–5 where 1 = none, 2 = poor/mild, 3 = moderate, 4 = good, and 5 = excellent:	
1	How strong was your sense of being involved in the visual environment?
2	How strong was your sense of events occurring in the real world around you while involved in the environment?
3	How strong was your sense of being involved in the experimental task?
4	How strong did you feel comfortable inside the environment?
5	To what extent did you feel confused or disoriented at the beginning of break or the end of the experimental session?
Please rate your experience for each question on scale of 1–5 where 1 = very quickly, 2 = quite quickly, 3 = moderate, 4 = quite slowly, and 5 = very slowly:	
6	How quickly did you adjust to the AR environment experience?

Considering the turn-taking technique in our experiment, we also have other quantitative factors to be measured. Novices’ time taken to achieve their turn will be calculated and compared with the control group. Additionally, the number of queries and questions made by the novices, which indicate their progress in learning, will be taken in account and measured too.

In addition, the learning outcomes for the users, which is based on novices learning the rules for a new game, will be measured based on the participants (novices) learning achievements as well as the feedback of participants (experts). Their achievements will be recorded as marks during the learning process. These marks will be compared with the control groups marks later on to basically evaluate the performance of learning in our experiment.

5. Conclusion and Future Work

With the increasing development of display technologies such as smart glasses, handheld devices and AR tools, we have demonstrated in this work-in-progress paper a further elaboration and development of our MiRTLE+ system to enhance the collaboration between remote students in a mixed-reality smart classroom using AR technologies and various handheld and head-mounted devices. Our paper mainly focuses on exploring the learning effectiveness based on several factors; the students' sense of presence, engagement, and immersion in a smart mixed-reality space (across different scenarios, immersive interfaces and learning tasks). Our initial proposed learning activity is based on a well know card game which will be used for the quantitative evaluation of the system with expert and novices learners. Furthermore, our proposed qualitative evaluation is based on several established frameworks for measuring the aforementioned factors in 3D virtual and mixed reality spaces. We are aiming to present the results from this research in future publications.

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Virtual Worlds for 3D Visualizations

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Abstract. This paper presents an analysis and discussion of visual information representations in multi-user avatar-based 3D virtual worlds. We discuss benefits and issues of such environments for displaying scientific and information visualizations. In comparison to traditional two-dimensional representation forms, virtual worlds can be used to display more dimensions of information and illustrate data with real-world metaphors. Additionally, their collaborative and social character allows new ways to explore and experience visualizations. However, the design, implementation, and integration of three-dimensional visual representations in such environments are more challenging than for 2D representations. Thus, only a few visualization forms are reasonable. In this paper we reflect on implications for more useful 3D visualizations and introduce and discuss these on own examples.

Keywords. Visualizations, Visualization Techniques, Virtual Worlds, Immersive Worlds, Collaborative Environments

1. Introduction

In recent years there has been considerable interest in the examination of new user interfaces to display and explore scientific and information visualizations. Innovations in 3D technologies such as virtual reality devices offer new possibilities to graphically illustrate and interact with information in 3D. Although many authors have discussed and analyzed benefits of visual representations in 2D over 3D, the introduction of these devices and recent innovations in 3D graphics have renewed the discussion about application areas and potential benefits of presenting and exploring information in 3D.
An important issue of scientific (visual representation of scientific phenomena) and information (visual representation of data) visualizations is the successful representation of data connected to specific object or environmental information. The traditional forms of visualization technologies often use abstract elements, such as lines or pies, to illustrate data. Three-dimensional visualizations cannot only be used to integrate more dimensions and enable viewing information from different angles and views, but also to present data with visual metaphors. For instance, real-world models such as the replication of a city can be used to visualize data linked to geographical information.

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The current trend towards three-dimensional user-interfaces and interaction possibilities such as holographic display, 3D printing, and airborne haptics is and will enable new technologies for visualizations (Robert et al., 2014). Also, the current introduction of different virtual reality home solution and immersive gaming interfaces will allow affordable and more immersive solutions for different kinds of visualizations. One way to interact with these immersive virtual reality devices and make use of different 3D interaction interfaces are 3D virtual worlds. Virtual worlds can be avatar-based or designed from the first-person perspective. They can be designed as multi-user community environments, or as single-user worlds. In the following sections we will focus on collaborative community-based virtual worlds.

Although much research has been done using different 3D technologies to visualize data, only a few authors have described their experience with collaborative multi-user virtual worlds for presenting visualizations in a collaborative setup. Virtual worlds support several new options for displaying and exploring scientific information and abstract data. The 3D capability turns 3D virtual worlds into excellent environments for displaying and interacting with phenomena and datasets. Their collaborative character enables users to create, explore, and discuss visualizations with other users. Their ability to present data linked to geographical information and to use real-world metaphors make them into powerful tools to explore information in a realistic setup. However, the design and integration of three-dimensional information presentations in such an environment can be an overhead for simple datasets.

But what kind of visualizations should be integrated into virtual worlds? What kind of representational forms should be used to enhance the user experience? The aim of this paper is to describe and discuss potential application scenarios of virtual worlds for scientific and information visualizations, assess how well they are suited, and discuss prospects and issues.

2. Background and Related Work

In the first section, prior work that explores three-dimensional information visualization techniques is reviewed. After that, virtual worlds are introduced and work on 3D animations, simulations, and visualizations in such environments are summarized.

2.1. Information and Geographic Visualizations in 3D

Information and geographic visualization in 3D can be used for instance to represent multi-dimensional datasets, such as a mapping of data (e.g. amount of rain, air pollution) with geographic location to observe the situation in a 3D world model. Several authors have discussed challenges and conditions of using 3D visualizations. While well-designed 3D visualizations are often visually promising, not every dataset is suitable to be presented in 3D. For simple datasets, the implementation in 3D might be not better for presenting the information than in 2D. Physical data, however, often require a three-dimensional representation. Unfortunately, the design, implementation, and processing of visualizations in a 3D space are significantly more time- and cost-intensive. Advantages of using 3D applications to present data include the possibility to add additional dimensions and new viewpoints (Card, Mackinlay, & Shneiderman, 1999), and to maximize effective use of the screen (Robertson, Mackinlay, & Card, 1991).

Many authors describe positive experience with 3D visualization forms in different application areas. McCahill and Erickson (1995) discuss an early design for a three-dimensional spatial user interface for the information system Gopher. GopherVR[2] uses 3D visualizations for displaying information in the form of 3D scenes. The user interface reminds of a computer game and is based on early virtual reality experiences. They use different 3D models to represent common icons in the 3D space. The authors already identified several user experience problems, such as navigation problems, grouping and relationship problems, browsing problems, and different interactions issues. Robertson, Mackinlay and Card (1991) use cone trees to display hierarchical information structures in 3D.

Several systems use real-world metaphors as information space for displaying abstract data (Rohrer & Swing, 1997). One of the most famous examples in exploring three-dimensional interface forms for visualizations is described by Robertson, Card and Mackinlay (1993). The authors discuss the Information Visualizer, a user interface for an information retrieval system. They use 3D-room metaphors to illustrate workspaces. Rohrer and Swing (1997) visualize web search results in a 3D information space. They also use a 3D-room metaphor, where objects in the room link to specific information. Keskin and Vogelmann (1997) describe cityscapes metaphors as generalizations of bar charts to represent hierarchical and network information.

Andrews (1995) describes an early 3D visualization system known as Harmony Client. The system supports different three-dimensional visualization facilities. The Harmony VRweb 3D scene viewer can be used to explore scenes filled with information (e.g. a plan of a city offering information about sights of the city with embedded hyperlinks). Harmony's Information Landscape visualizes collection structures and users can navigate through this landscape. Different 3D icons can be used to represent different document types. Tomenski, Schulze-Wollgast and Schumann (2005) describe an approach to visualize temporal data on maps. They use 3D pencil and helix icons and combine them with a 3D map display to represent temporal dependencies on the map.

The above systems use 3D real-world metaphors, such as rooms, landscapes, or cities, to present information. Virtual worlds can enrich such environments with additional components, such as multi-user capability, which enables social and collaborative activities. In the next section, we will explore work on three-dimensional animations, simulations, and visualizations in virtual worlds.

2.2. 3D Visualizations in Virtual Worlds

Virtual worlds are defined as shared, persistent virtual environments underlying physical rules, where players, represented as avatars, can communicate with each other and interact with the world in real time (Bartle, 2004; De Lucia et al., 2009). They are efficient environments for representing three-dimensional objects, animations, and interactive simulations. Their multiuser support allows different collaborative and social activities. Hence, virtual worlds have become a popular tool for applications in areas such as training, simulation, or design (Benford et al., 2001). Different authors also describe the users' feeling of presence as a significant advantage over traditional

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[2] http://www.floodgap.com/software/gophervr

communication platforms and communities. This feeling is also known as "being part" of the virtual world (De Lucia et al., 2009; Witmer & Singer, 1998.

Studies suggest using virtual worlds in particular for application scenarios that make use of their three-dimensional objects and their interactive nature (Pirker et al., 2013). There is only little work on the use of multi-user virtual worlds for displaying three-dimensional information visualization forms. However, several authors have described collaborative setups, which integrate 3D applications, animations, or simulations in virtual worlds, and which can further be used and extended to create scientific or information visualizations.

Pirker et al. (2012) describe a prototype system, the Virtual TEAL World, in the context of remote physics education. The virtual world is designed to teach students principles of electromagnetism and uses interactive three-dimensional simulations to display electromagnetic phenomena. The collaborative character allows students to remotely discuss the phenomena illustrated by the simulation and solve assignments in-world together. A similar approach is used to teach students programming concepts by visualizing the behavior of a sorting algorithm (Pirker, Gütl, & Kappe, 2014). Both examples use three-dimensional simulations and animations to make unseen phenomena visible. The collaborative setup gives students the possibility to learn and work together.

While many authors have described systems that use 3D visualizations for learning and training, we know little about virtual worlds for scientific and information visualizations, either for explanatory, or exploratory usage. Most studies present visualizations in three-dimensional single-user applications, which use real-world metaphors. These metaphors are perhaps the most well-known visualization form of data in 3D environments. They allow users to explore the content in a familiar environment.

Fokaefs et al. (2010) discuss the use of 3D visualizations in Open Wonderland. They use a city metaphor to display information and statistics about software and communication artifacts. The dimensions to graphically illustrate data are building types, building color, height of the building, and proximity within city blocks.

3. Application Examples

There are numerous application examples, which can take advantage of collaborative three-dimensional multi-user environments. In the following section we will discuss potential scenarios, implemented as a first prototype in the virtual world toolkit Open Wonderland, which illustrate visualization scenarios especially designed for 3D virtual worlds.

3.1. Open Wonderland

Open Wonderland[3] is a collaborative virtual world with focus on extensibility (Kaplan & Yankelovich, 2012). Several modules allow the integration of different three-dimensional visualizations and animations. Users are represented as configurable avatars and can use a text-chat, VoIP, and gestures to communicate. 3D models to

[3] http://www.openwonderland.org

design and create a virtual environment can be dragged and dropped into the virtual world. New features (such as visualizations) can be integrated in form of modules. Open Wonderland also provides different tools to enhance discussions, brainstorming, and collaboration. This includes virtual white-boards, the option to share applications, and immediately contribute pictures and documents either from the desktop or the web (by dragging and dropping a document into the virtual world client).

3.2. Scientific Visualizations

An advantage of presenting scientific visualizations in virtual worlds is the ability of visualizing phenomena in a multi-user environment, which is remotely accessible and supports collaboration. Proving an integrated shared environment for scientific visualizations to scientists will enable them to explore phenomena and work together on their research. They can meet in the virtual world and use it as platform for cooperative research, discussions, and brainstorming. Multi-user virtual world environments support collaboration in the form of VoIP communication, knowledge and data sharing, or working together on in-world shared applications. As many modern teaching approached (in particular in STEM education) focus on peer- and group-learning activities, the cooperative discussion of visualization is key to successful learning experiences.

By providing scientific visualizations to students, a learning tool can enhance their conceptual understanding of the phenomena. In particular, possibilities to interact with such visualizations can help them understanding the concepts.

In Figure 1 (a) (an example of the Virtual TEAL World), the physical concept Faraday's Law is simulated and concepts that are usually invisible (in this case field lines) are visualized. Figure 1 (b) illustrates the behavior simulation of different sorting algorithms with colored marbles. Both visualizations were designed as learning tools and implemented as modules in Open Wonderland (Pirker et al., 2013; Kaplan, 2012) and can easily be extended to meet the requirements of specific scientific visualization scenarios.

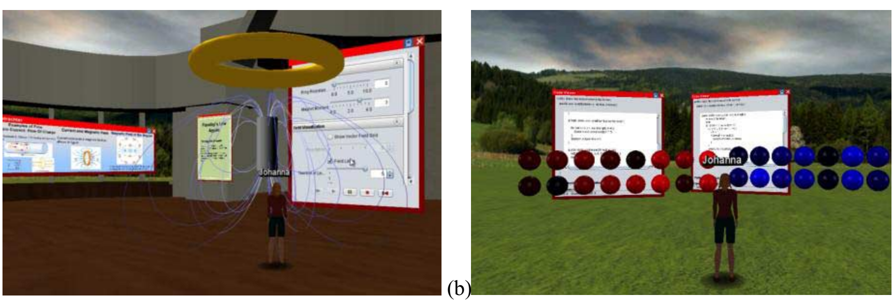
(a)  (b)

Figure 1. (a) Visualization of physics phenomena. (b) Illustrating algorithm behavior in 3D.

First studies with the simulation framework in Open Wonderland were conducted, which are discussed on the example of the Virtual TEAL World in detail in Pirker et al. (2013). The evaluation shows that interactive features of such visualizations in particular can optimize the learning outcome and the user engagement. One factor, which was particularly important for test users, was the integration of collaborative activities to create interesting and motiving learning environments. A first prototype of illustrating different sorting algorithm in an immersive learning environment is in development. This prototype will be first tested in a virtual reality setup (an immersive experience with a head-mounted virtual reality device) and then in a collaborative multi-user virtual world setup. With user studies we want to focus on open research questions such as (a) can immersion improve the user's understanding or perception of the scientific visualization, (b) does a collaborative learning setup improve the student's learning progress and understanding of the visualization.

3.3. Information Visualizations

Virtual world environments are well suited to illustrate different dimensions of data. In the following, we describe two application scenarios that use a geographical representation to present location-based data. In both examples, real-world metaphors are used to represent data. Users can either explore the environment alone, or meet other users to discuss and explore it together.

In Figure 2(a) presents statistics of traffic volume in different parts of a city. Simple three-dimensional models of cars are used to illustrate car frequency. Dimensions of the visualization can include the frequency, size, type, and color of the rendered cars. Since the virtual world supports high-fidelity audio, sounds could also be a further dimension to illustrate data. Figure 2(b) visualizes location-specific pollution statistics. Data is presented using the size and density of dust clouds to visualize the pollution in specific city areas, as can be seen in the figure.

(a) (b)

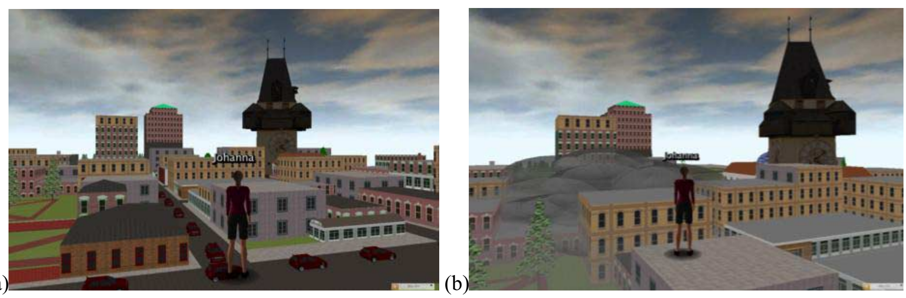


Figure 2. (a) Visualization of traffic volume in different parts of a city and (b) Location-specific pollution statistics. The avatar can be used to explore the environment in an immersive way. In a multi-user setup different avatars can explore and discuss the visualization together.

In both examples, users typically explore the environment by walking through the area to "experience" the visualization, or by flying over the city to get an overview. The collaborative and interactive settings enable the users to discuss the visualizations and interact with the environment. Through the virtual world's ability to enable users to experience visualizations together, perhaps new forms of virtual and remote information exploration can be studied.

First prototypes of these visualizations have been integrated into Open Wonderland. As a next step of this work-in-progress, first user studies and comparisons with similar two-dimensional applications are necessary to evaluate the prototypes. After that, an implementation is planned which is able to render data dynamically and considers the outcomes of the user studies. These studies are in particular important to answer still open questions such as (a) advantages and disadvantages compared to other visualization methods such as 2D map based visualizations, (b) would users like to walk through visualizations, (c) does the immersive character change the user's perception of the visualization, (d) would users benefit from the collaborative multi-user capabilities.

4. Conclusion and Future Work

In this paper we have discussed advantages and issues of using collaborative virtual worlds for scientific or information visualizations. To summarize, we believe that a collaborative setup in 3D virtual worlds can enhance the exploratory settings of such worlds. The prospect that virtual worlds for visualizations offer is that innovative collaborative exploration forms are possible. While scientific visualizations in collaborative 3D learning setups have been proven to be valuable learning tools, it is challenging to find application scenarios that are suitable for collaborative 3D information visualizations. Work on the introduced application scenarios is still at an early stage. Future work will involve the evaluation with user studies of the application scenarios with focus on the (a) advantages and limitations of collaborative aspects, (b) comparisons of the scenarios with similar 2D visualizations, and (c) advantages and limitations of immersive aspects.

At the moment, virtual world environments still face different technical (scalability, technical requirements, band width) and social challenges (learning new interaction-forms, prejudices against virtual worlds or game-like systems) (Benford et al., 2001). With the introduction of innovative and affordable virtual reality devices, 3D visualization forms in virtual environments provide additional options for displaying and exploring data and render it more interesting to users again. Also different enabling 3D technologies that support different input and display options are promising future supporters of 3D visualizations that can enhance the users' feeling of immersion. Thus, we will focus our research also on comparing different three-dimensional visualization strategies in immersive settings supported by head-mounted virtual reality devices combined with interactive interactions forms provided by tools such as the Kinect.

Whether three-dimensional information visualizations bring us more information or are less convenient for users has been widely debated. The present discussion demonstrates that well-designed visualizations in multi-user virtual world environments can open up new opportunities of exploring and discussing data in a collaborative and social way.

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Tweedback goes Smart Watch — Why Classroom Response Systems Need Smart Watch User Interfaces

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Abstract. We present classroom response systems (CRS) of the second generation, which are using mobile devices of students. We describe their communicative advantages and aspects of their user interfaces. We explain the requirements for a novel user interface for the lecturer and suggest how smart watches may provide a solution to this problem.

Keywords. classroom response system, smart watch, user attention management, multitasking

1. Introduction

A lecture in front of a large audience is a bad didactic concept. It builds on the idea that the lecturer is skillful enough to provide a presentation sufficiently interesting to catch and keep the attention of several hundred students inside of a stuffy lecture hall for a time span of two hours. This approach to instruction might have been perfectly valid in an age of expensive books, where the main task of the students was to act as copying machines, writing on a sheet of paper what the lecturer was reading to them. This becomes quite clear in the German translation of the word lecture, which is *Vorlesung* and indicates that the instructor is reading a text in front of an audience.

From a didactic and psychological point of view we are well aware of the drawbacks of such an educational setting. Especially in a world of mobile, Internet-capable devices, such as tablets, smart phones, smart watches and smart glassware, the drawbacks of a traditional lecture become clearly visible. Therefore, in recent learning technology research we see many attempts to modify the setting of a lecture for large audiences.

A first trend was to use electronic media for delivering lecture material to students. It forms an important aspect in contemporary learning but it also leads to a dangerous trend: If a student can access material on digital channels, where is the incentive to participate in a lecture and benefit from all the other instructional advantages of real-life teaching, such as observing a role-model, receiving feedback on own perceptions and theories,

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exchanging thoughts with other students of being part of a social structure or learning group. We therefore need technical as well as didactic tools for morphing the traditional lecture into more attractive and interactive events for the learner.

One important drawback is the communicative distance between the teacher and the student. Classroom response systems (CRS) provide a technology for addressing this issue and they have already reached quite a mature development stage [7], [8]. However, as we shall argue in this paper, there is still plenty of room for improvement for the user interface of the lecturer; many issues may be solved by employing a smart watch.

This paper analyzes the difficulties which current CRS pose with regard to their lecturer user interfaces. Using our own CRS implementation *Tweedback*, openly available at `http://twbk.de`, [6], for a case study, it constructs a case for a smart watch based approach. The contribution describes ongoing research.

The paper is structured as follows: In Section 2 we describe classroom response systems (CRS) as an approach for improving the communicative situation of a large lecture. We introduce our own CRS Tweedback and describe experiences with it. Section 3 describes current problems with the lecturer interface and Section 4 illustrates solutions to some of these problems; finally we describe further work to be done in the area of smart watch based CRS.

2. Classroom Response Systems (CRS)

The goal of a CRS is to improve the communication between the lecturer and a usually larger number of students.

Initial implementations of these systems consisted of *clicker systems* through which students could participate in real-time quizzes in class [7,5]. As multiple choice instruction is a preferred instructional technique in the medical field, these devices are particularly well accepted in this discipline. Besides being the favorite form for conducting examinations in medical school, multiple choice scenarios also enable additional didactic settings. For example, the doctors-to-be are listening as the instructor provides details of a simulated doctor-patient interaction. The students chose diagnostic and therapeutic answers on their clickers. They may pose questions or suggest additional medical tests, as the case unfolds in class. As soon as a certain percentage of attendants suggest the correct diagnosis or treatment, the next case is started. The experience, how additional symptoms or test results direct the audience to fresh diagnosis choices can provide an important learning effect for the students. Also other academic disciplines use these tools [8,11].

Clicker systems, also called the *first generation* of classroom response systems, however, have a serious issue: Devices have to be bought, distributed to students, collected, charged and maintained. Usually, proprietary interfaces are used and the integration into existing elearning systems proves difficult.

A *second generation* of classroom response systems uses portable networked devices of students. As smart phones and tables are ubiquitous among young people, all device-related issues may be considered solved. Communication takes place over Internet connections, data is exchanged in standardized and open formats, finally user interfaces are provided in HTML.

Tweedback is a modern second generation CRS which was developed in our research group and forms the basis for a number of communicative and didactic studies in this field. Initially we offered three tools [6].

(1) A *chatwall* through which students can pose short questions of at most 140 characters to the lecturer. The participants can vote for important contributions and thereby indicate to the teacher that a large percentage of the audience is interested in an answer to a particular problem.
(2) A *panic button* enables the students to indicate problems in class which they are aware of but feel unable to express in the form of a chatwall contribution.
(3) A *quiz* feature finally allows to conduct multiple choice tests as with the traditional clicker systems.

The students use the system via any of their Internet-enabled devices, whereas the lecturer receives a tablet on which he or she can monitor student activities.

The system is well accepted by the students, in small as well as large auditoriums. We soon realized the important didactic and communicative impact of Tweedback on lectures. For example, the chatwall was not only used to ask questions to the lecturer, but the students also embraced this as an opportunity to provide answers by themselves or to produce spam on the anonymous channel. We understood that a fresh didactic setting and a new interpretation of the tasks of a lecture is helpful. More studies regarding the learning effect of Tweedback are currently conducted.

3. Problems with the Lecturer User Interface

However, we also realized that the current user interface for the lecturer does not yet realize the full potential of the concept. In particular, we identified the following issues:

Number of interactions: A lecturer easily becomes overwhelmed by the considerable number of interactions which a large audience might produce. Typically in a 90 minute class of a 100 person audience, between 20 and 100 chatwall interactions are written, of which 2 to 15 warrant an answer or a reaction by the lecturer. To solve this problem, we designed a crowd-sourced filtering mechanism: Students can vote for chatwall contributions, can remove contributions of other students from their CRS screen and can delete their own contributions from the entire system. As a result, the system can determine audience popularity of the contributions and present them to the lecturer according to this popularity. This helps the lecturer choose those questions he wishes to discuss in class. Unimportant questions can be removed from the lecturer user interface and special markings can be provided to questions requiring individual treatment. These features help the lecturer cope with a constant flood of messages.

Attention latency: Currently, a lecturer once in a while checks the screen of the CRS to decide if a contribution warrants an answer in class or whether a significant number of participants have pressed the panic button. However, there may be cases where the latency from student intervention to lecturer reaction takes too long: A question is asked on a topic on slide 3 but the lecturer realizes this only when she already has advanced to slide 35. Also the application of the panic button requires a fast reaction by the lecturer in order to be useful.

Mobile lecturers will not always stand next to the CRS screen but wander in class. He or she might develop a fresh set of ideas on a whiteboard, walk through class to be physically closer to the students during a discussion, or stand next to an exhibit or experimental device. Especially during these moments contributions on the chatwall can add value to the instructional interaction, but the lecturer is not able to see the CRS screen.

Visual overload: During a lecture the attention of the lecturer is split between the current slide, the audience and the overall organization of the class. The lecturer has to watch several screens, i.e. the projection and the screen of his laptop, usually displaying the current slide, some lecture notes as well as a preview of the next slides. With an audience response system, the lecturer has yet another screen to watch. It proves difficult for the lecturer to properly split the attention between all these screens.

Lost in-class interaction: Preferably, the lecturer will download a Tweedback transcript in PDF and add comments into the stream of questions. However, the responses given in class and the resulting discussion is lost. It would be beneficial if the audio stream of the interaction could be saved and provided to the students.

Lack of interaction integration: The common interaction interface for a lecturer in class is the presenter device, which advances to the next slide. The CRS provides a second and different interaction interface. In contrast to the presenter, which is mobile, it resides on a stationary tablet on the desk of the instructor.

4. Lecturer User Interface with a Smart Watch

From our prototypical experiments we understood that most current problems with the lecturer user interface can be solved by a smart watch or a similar wearable device.

4.1. Core Advantages of a Smart Watch

The core advantages of a smart watch for a CRS application are:

(1) Mobile, wearable device, which stays with the lecturer at all times during class and does not require active attention.
(2) Notifications which can be implemented on a tactile, vibrational channel. An acoustic channel lacks the necessary discretion in class and a visual channel would increase the cognitive overload on the lecturer.
(3) Input which can be provided via simple haptic gestures at the place where the lecturer receives a notification.
(4) Speech-to-text conversion which allows to upload a transcript of the answer of a lecturer to the chatwall.
(5) Light-weight visual interface to the lecturer.

As a wearable device the smart watch has direct contact to the body of the lecturer. Vibration signals immediately gain the focus of the instructor and solve the problem of attention latency and mobile lecturer. The tactile mode of communication has another important advantage. In the theory of multitasking it is well known [9,10], that it is much easier for humans to process a tactile signal together with a visual signal than react on two simultaneous signals of the same kind.

The screen of a smart watch is large enough to present a single chatwall interaction and further details on the nature of the interruption. Upon interruption, the lecturer checks these details and provides the CRS with further instructions by a simple gesture.

Figure 1. Smart Watch: Notification of a chatwall interaction, content of interaction. For a comparison with the original user interface, visit `http://twbk.de` on your device.

As most smart watches contain acceleration sensors as well as touch screens, single hand gestures (shaking or moving) and two hand gestures (tapping or wiping on the screen) are possible. This variety of gestures is wide enough that the presenter device interaction can be integrated with the CRS interaction into one smart watch. As added benefits, the smart watch can also solve two traditional problems of the presenter device, by providing the lecturer with abbreviated notes, the title or a thumbnail of the next slide, even when the lecturer is not in front of the presentation laptop. The current interaction modes and battery capacities of a smart watch require some activation by the wearer and will not support continuous display operations.

Most contemporary smart watches are not autonomous devices but augment the functionality of a smart phone, to which a Bluetooth link is established. We currently implement the connection of the smart watch to the CRS via a smart phone, which the lecturer carries with him. Thus, we maintain a data link to the server even when the lecturer is far away from the base device (usually a tablet or a laptop).

A certain amount of lecturer input is helpful. For example, the lecturer might chose to ignore an interruption in order to finish a particular explanation and then forgets about the interruption. The system therefore should know, whether the lecturer has dealt with a topic or wants the system to repeat the interruption of the lecture in a kind of *snooze* mode. With the smart watch the lecturer does not get yet-another-screen to watch but focused notifications; she no longer has to keep an eye on the CRS all the time.

For the quiz mode of a CRS a preview of the lecturer on the current status of audience responses is helpful. Also a quick-start feature for prepared quizzes is possible.

4.2. Prototypical Tests and Results

Our current prototypes are based on the LG G Watch, LG G Watch R and the Moto 360 models. The software is built as an Android application, which is running on a smart phone or tablet. This enables direct communication between mobile device and connected smart watch. Developing a native application is necessary to ensure full access to the smart watch and to add an optional smart watch-only application. Web based applications currently cannot communicate directly with smart watches. The software is built around the Android Wear toolkit, which has complete access to the smart watch screen and the required sensors. We have implemented various test scenarios for notification and user input and have observed the reaction of lecturers in various test scenarios.

As main problems we noticed a considerable impedance mismatch between the functionality available in the smart watch and the functionality needed by our system. This situation is understandable, as a CRS of course is not the primary market for a smart watch manufacturer.

Example 1: Vibration signals can be defined by prescribing time frames of vibration and non-vibration. However, a standardized set of signals of different urgency and importance, which is available and valid across all applications, has not yet emerged.

Example 2: Speech-to-text conversion expects short messages without breaks. The answers of the lecturer are longer and may contain moments of silence during which the lecturer prepares his answer. The API currently interprets them as end of the contribution and stops listening. Moreover, privacy issues arise, since only the first activation of the audio recording is processed locally and the remainder is sent to a Google server.

Example 3: Interaction with smart watches currently works very well using the touch screen. This is not always appropriate, as a lecturer may not have both hands available for a screen interaction. Rather, a quick one-handed gesture will be the normal case. For example, a quick turn of the wrist to the right might signal *next slide*.

Example 4: Motion gestures on smart watches can be detected through a variety of sensors, especially accelerometers, gyroscopic and magnetic sensors. However, reliable and repeatable detection of a predefined gesture still is in it's infancy. There is a high level of noise in the sensor readings, gesture recognition still consumes a lot of CPU resources or requires transfer of data to the connected phone or pad [3]. It is still difficult to distinguish intentional from unintentional gestures [1,2].

Example 5: More automatic support for the user interface is needed. It is easy to forward chatwall contributions to the smart watch and to display them on a scrollable text viewer. However, the lecturer does not always have a second hand available for doing the scroll. The smart watch understands on its own from motion sensing when it is looked at, but it must also start and stop scrolling on its own or based on one-hand gestures.

A further issue is the yet small dissemination of smart watches. Many of our lecturers wore a smart watch for the first time when testing the CRS. Although most of them were computer savy, they were not yet familiar with the typical interaction modes used on the particular smart watch model. It proved very helpful to add small iconic arrows, which hinted possible touch interactions. Also the generic *Ok Google...* hint was understood by most. However it is still unclear how hints for motion gestures could look like.

As all these findings currently are of a qualitative nature only, we currently are planning a systematic user study on the advantages and draw backs of smart watch interfaces to Tweedback.

4.3. Other Form Factors

Besides smart watches, there are many other wearable form factors, from augmented reality glasses to smart rings, health trackers and simple vibrating devices. Currently, none of those are on our shopping list, as they are research prototypes instead of affordable and standardized end-consumer devices, or as they cannot be used for the needs of our user interface. A vibrating health tracker, for example, can draw the attention of the lecturer but it lacks proper I/O possibilities.

Smart glasses seem to be the most promising form factor from a pure research perspective. They combine reasonable processing power, discrete text output and tap, audio and video input. No doubt, these devices are promising research objects. However, the video camera raises privacy concerns to an extent that numerous locations already ban the use of Google Glass although this device has not yet been launched commercially. Also, the form factor has a certain coolness, which may be good for a computer science seminar on augmented reality but which is in conflict of our goal to improve all kinds of lecture and learning experiences.

Smart watches, in contrast, are simple digital extensions of the very widely accepted form factor of the wrist watch. They are non-obtrusive, commercially mature, technically stable and do what they are expected to do.

5. Conclusions and Future Work

As CRS become more wide spread, a common set of concepts, objects and interactions will emerge. We see a need for a de facto standard of features and interface concepts, as we have it currently for presentation programs.

Similarly, a *standard gesture vocabulary* for smart watches must be developed further. While there are many promising results on advanced gesture recognition [4], the important problem for application design is *user adoption* of gesture-based interaction vocabularies.

The *granularity and differentiation* of interaction vocabulary in class room scenarios must be evaluated. A lecturer might, for example, distinguish five different vibration notifications in a test run. However we need to know how reliably they are detected when lecturer attention is focused not on the device but on the content of the lecture. The gesture of a left or right turn of the hand might signal *next* or *previous* slide, but the gesture should not be issued unintentionally when the lecturer cleans the blackboard or points to objects in class.

Moreover it will be important to *make a didactic case for smart watches*. We believe that the pertinent discussion will be similar as in the case of CRS. Critics of CRS sometimes mention that students as adult humans can also raise their hands and voice their remarks without needing recourse to digital devices. While this remark certainly has some merits it does not reflect the full truth. In large audiences of 100 and more participants, there still are shy students who do not want to expose themselves by asking a stupid question. A lecturer might not see a single raised hand in a large lecture hall. The anonymous character of the chatwall as communication channel also allows the students to voice critical remarks of the instructional event, which can provide important feedback to the lecturer which otherwise would go unmentioned. If a lecturer reacts to a question, the reaction will commonly be to a singled raised hand. Neither the lecturer nor the student asking the question will know whether the question is an important one which should be discussed in front of a larger group or is of interest only to a minority and should rather be settled after class or by email. It is therefore a matter of time economy that a lecturer will discuss only a small percentage of student questions in class. A chatwall with voting functionality enables the lecturer to focus on the questions bothering the majority of students.

In the end it needs quite some practical experience with CRS and an adaption of the chosen didactic approach to fully realize the possible benefits of the system. The same is true for the obvious disadvantages of a CRS. Chatwall spam, for example, can be a matter of concern: Lecturers who accept a considerable amount of background noise and student inattentiveness in class and have developed their own technique to deal with it get irritated by even a small number of irrelevant comments on the chatwall. In our observation the problem is not technology but didactics. Inattentive students will not become attentive by turning off a CRS. However, a CRS may provide additional insight into the mind set of the students – which then requires suitable reaction of the instructor. We have a good understanding of these issues and know how to communicate solutions to lecturers who want to use our CRS [13]. We expect a similar set of issues with a new lecturer interface.

We have not yet considered use cases of wearables for the student interface of a CRS. While it seems feasible to provide a small number of such devices to our lecturers, they are not yet in common use with our students. Moreover, we want to gather practical experience with the docent interface first. We agree, however, to the interesting suggestion of one of the reviewers and placed this issue on our medium term research agenda.

From the adoption of our own CRS Tweedback in other faculties than our own, technical faculty, we realize that *social acceptance* and *ease of use* is much more important than the purely technological quality of the system. If smart watches shall be a success in electronic learning it is imperative that this connection is observed and honored.

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Self-Regulated Learning in Virtual Worlds – An Exploratory Study in OpenSim

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Abstract. Computer technologies are increasingly used in education to give the student more autonomy, referred to as *student centred learning*. One of the assumptions often made in this situation is that students will *self-regulate* to ensure they achieve the intended learning outcomes. Learning in immersive environments is popular as they are engaging, entertaining and flexible. However, a potential tension exists between configuring a multi-user environment to prohibit actions that can disrupt learning and maintaining the freedom and flexibility that generates learner engagement. This research investigates the importance of student self-regulation for learning in OpenSim. The outcome suggests self-regulation is one of the most important factors needed for successful learning within OpenSim as it preserves engagement while dissuading disruptive behaviour. Moreover, the need for suitable user support is identified as key for promoting student self-regulation within OpenSim.

Keywords. OpenSim, self-regulation, immersive environments, managed learning

1. Introduction

Virtual 3D environments that support multiple users are referred to as 3D Multi User Virtual Environments (MUVEs), or virtual worlds. These have proved sufficiently successful in educational applications to be seriously considered for mainstream use [1]. However, MUVE management can be challenging: academics can find that the underlying system functionalities and use cases are less cohesive than conventional online facilities, while students can be overwhelmed by the rich and engaging nature of 3D immersion and might focus more on environment features rather than the intended learning outcomes. To address the challenge of managed learning in virtual worlds this research investigates the self-regulation of learners within a MUVE. The findings suggest that appropriate management of MUVEs and the provision of suitable user support can promote educationally beneficial self-regulatory behaviour by students.

This research refers to the common understanding of *MUVE*s that allows users to interact and explore a 3D environment without predefined goals or story plots. Problems in this domain are investigated using two widely used and closely related MUVEs: Second Life (SL) [2] and Open Simulator (OpenSim) [3]. The research provides its recommendations and contributions with respect to these MUVEs. There are many previous studies and literature on using SL/OpenSim for education, but for brevity, those are not included into this discussion.

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In the common didactic educational mode students expect the teacher to tell them what to do, how and when to do it, and when to stop doing it – an approach that is open to the criticism that it relies solely on a behaviourist pedagogy where information is transferred from teacher to student rather than cultivating critical, creative and original thinking skills in the learner. Similarly, too much external regulation (forced) can introduce negative results in student centred learning [4]. This is a crucial factor for OpenSim based learning since the advantages of MUVEs that facilitate a range of modern pedagogies recommend only adequate levels of guidance and control and allow students to regulate their learning. Too much external regulation can inhibit the advantage of MUVEs while too little can fail in achieving the learning goals. The research focus of this paper is on this unexplored area in the quest to support academics and students having an effective learning experience in immersive environments.

Section 2 of the paper presents background literature and related work. Section 3 elaborates on system features of OpenSim that can affect user self-regulation during learning. Section 4 presents findings of an exploratory study examining avatar self-regulation within OpenSim based learning sessions and Section 5 concludes the paper.

2. Background and Related Work

Self-regulation is a behavioural trait suggesting individuals behave with self-control according to the context and environmental factors of their work. This concept of students behaving with a restrained approach imposed by their desire to achieve learning objectives has been developed as a learning paradigm and widely researched in traditional and e-learning environments. Self-regulated learning has been described in [5] as a collection of self-generated thoughts, feelings, and actions, which are systematically oriented toward attainment of student goals. Pintrich defines self-regulation as "an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behaviour, guided and constrained by their goals and the learning environment contextual features" [6]. This is important when promoting self-regulated learning in virtual worlds. The consideration of environmental context and its attributes are significant for supporting learner engagement and effective learning in MUVEs.

Schunk [7] has suggested that there is a need for more research aimed at improving students' self-regulatory skills and to examine how learning environment contexts affect the amount and type of self-regulation displayed. In a study [8] of immersive learning activities authors reported distractions from learning when students behaved as if they had forgotten what their ultimate learning goal was e.g. they repeated actions without any particular meaning. This may have been because the students had forgotten their learning tasks. Virtual worlds can provide a better learning experience when students self-regulate as the activities are learner centric [9]. Students with higher self-regulatory skills tend to be more academically motivated and display better learning [10]; this is relevant to learning in MUVEs since students often follow exploratory and collaborative forms of learning.

A modified self-regulated learning model has been developed for augmented environments supporting adult learning [11]. The authors highlight the need for tailored self-regulatory approaches to fit with the domain of the learning environment. Wan and Reddy [12] have examined self-regulated learning practices combining the idea of a community of learning in MUVEs (OpenSim) with avatars. They argue that the conventional self-regulatory learning model which is based on the individual student should be extended for MUVE learning since student avatars are part of the community. Students are not only responsible for their individual learning goals but also for the community that they are part of [12]. This indeed supports the validity of this research where self-regulation should be part of MUVE based learning, not only in the focus on learning but also for the environment interactions and avatar behaviours in-world.

3. Management Functions and Implications for Self-Regulation in OpenSim

An OpenSim environment can be managed through the following functional areas: land, content, avatar activities, groups and user access control.

For OpenSim, land management is the most important function category. User roles in OpenSim are often defined in terms of different levels of land ownership and access to land within virtual regions (a region is 256m x 256m size of virtual land). Multiple regions can be put together and form estates with estate owners and estate managers whereas a region can be subdivided into multiple parcels with parcel owners.

Content management is the next most crucial management area in OpenSim with functions for managing content objects and their permissions on different content related user roles. The Land-related permissions often get prominence over content-related permissions when manipulating and executing content objects, although these two permission models are defined in completely different contexts. As a result, land owners at different levels can manipulate the content related functions such as script execution, content creation, media streaming and content access inside their lands, provided that there are no conflicts between the content related functions at land levels. OpenSim content management follows a complex rule set for determining the effective permission level considering all applicable permissions and is also subject to unique permission models such as fair ownership, composite permission and cyclic permission loss; previous research has identified these models [1, 13].

Avatar activities are the ways users interact with MUVEs. Although the functions available in other categories can also be seen as these, avatar activities have a subtle difference in their nature. That is, there is a limited facility to regulate most of these activities, and even if controlled, this can severely affect the engagement generated by freedom of interaction. Avatar appearance change is unrestrictedly available for users to perform at their discretion - it is not expected to be managed by the land owners or the system administrators. For example, avatar mobility activities such as flying and teleporting can be controlled as part of land management. Extreme levels of control on avatars are also available such as freezing (disable all avatar actions), or kicking it off a simulation.

Group management allows avatars to perform in-world tasks as a group. Three default roles were identified: group owner, officer, and member; details about how group management interacts with other functions are discussed in [14].

OpenSim user access control is mainly based on user authentication to a simulation through the client viewer. Once authorized avatars experience the world subject to permissions applicable from other categories.

3.1. Implications for learning with self-regulation

One of the most significant means of promoting student behaviour with self-regulation is to link their avatars names to their real identities. Messinger (et al.) [15] have discussed the effect of avatar naming practices on user behaviour: "Individuals who "hide" behind their avatars cannot be easily identified, allowing virtual worlds to provide a certain degree of anonymity" [15]. Depending on the self-regulation level displayed by the students avatar anonymity can be completely harmless or extremely disturbing to the intended learning activity. The most significant challenge in managing land is to determine how land management affects the other management areas: user, content, group and avatar activity. Furthermore, conflicting conditions at different land levels (estate, region or parcel) can cause confusion for the users. Although, having more parcels may provide a good granularity to plan for more space with unique controls, such arrangements can bring an unprecedented level of complex management; students that show a high level of self-regulation can be a relief as they might not tend to exploit mistakes made by educators within an OpenSim setup.

Content management becomes important when learning activities are linked to assessments. It is important to understand the composite permission model when managing SL supported learning activities. For example, the student activities that involve scripting on their created content can affect the composite permission settings if there are conflicting permissions for the object and the scripts associated with it. In the cyclic permission loss scenario a creator of an object who transferred it to students to support their learning may not get the same permissions when the modified object is returned for assessment since students altered the permissions [13]. Fair ownership can let students accidently delete objects (and these are irreversible deletes, always). A high level of self-regulation can help prevent these actions and thereby reduce the adverse impact on the learning experience.

As Tay [16] observed, the functions available for managing groups are not designed to support group-based learning in formal education. However, roles and memberships are the two generic areas which academics can use for supporting group based teaching. One possible option is to define roles for the context of a learning activity and then delegate abilities to suit the requirements. However, there can be conflicting abilities at land, content and group levels, which with appropriate self-regulation can be managed without being exploited.

Control on avatar mobility can be useful for specific learning requirements that require students to be restricted to a given area. One of the avatar actions often disabled in OpenSim is pushing others, a concept borrowed from multiplayer games. Schroeder [17] found that regardless of the technological constraints and virtual world usage norms, users prefer to have exclusive control over their avatar design and their appearance in-world. However, activities such as changing avatar body shape, body parts, appearance parameters, clothes and wearable items can affect learning. For example, an unlocked educational content object can be worn and moved in cases where self-regulation is not practiced. Extreme levels of avatar constraint can cause severe impacts on the usability of the system and degrade the student motivation to engage with learning activities, although there can be a need to prevent unwanted behaviour of an avatar that affects the learning environment and other students. Effective learning management practices that promote student self-regulation can help to avoid such incidents.

4. Self-regulation in Learning in OpenSim – A Case Study

Importantly, engagement with the OpenSim environment may not necessarily represent engagement with learning, although there can be a positive correlation if the learning tasks are in constructive alignment [18]. However, if students do not engage with the simulated environment, there is a high likelihood that they will have low engagement with their other learning activities as well. Schunk [7] has suggested that there is a need for more research aimed at improving students' self-regulatory skills and to examine how learning environment contexts affect the amount and type of self-regulation displayed.

Wireless Island [19], a dedicated region for wireless communication education, was used for a case study in self-regulation. It provides interactive simulations for students to explore and also includes supplementary learning content such as lecture notes, lecture media streams and a museum of the history of wireless communication. 59 participants from two credit bearing modules, Data Communications and Networks (31 undergraduates) and Advanced Networks and Distributed Systems (28 postgraduates) took part; the study focused on student self-regulation within the environment.

As observed, students tried a range of constructions as well as editing the existing objects. Some of these alterations directly affected the learning experience; activities such as wearing the control buttons of the media display, moving and changing the internal arrangement of the lecture theatre, and creating constructs on the simulation area (shown in Fig. 1), should have been discouraged through management policies for effective learning. However, in this exploratory study, it was planned to observe such actions and use them as evidence to inform future work; hence, students were given unrestricted access to their environments. Some of the land alterations also affected the learning experience. Learning aids and content objects in a MUVE are put in-world with specific positions; if students change the terrain shape and land height it can completely change the intended learning experience. In extreme cases, the learning content may have been buried preventing students even seeing it, let alone accessing and interacting with it. This is a form of Denial of Service (DoS) attack in a MUVE context. One student interaction caused the learning environment to be significantly altered compared to its original layout (Fig. 2). This was a one-off incident, as the majority of students refrained from changing land settings. Compared to the postgraduate (Masters) students, the undergraduate (Honours) students showed high interactivity, resulting in a range of user-created objects, altered content and changed land terrain. The undergraduates were keen on exploring game-like features, and engaging their friends for collaborative activities, although those activities were not related to the learning. Students that were keen on completing their tasks may have had less motivation to explore the MUVE, however. Students were allowed to follow their preferred behaviour as a mean of learning through exploration without any restriction. An assurance was given that their behaviour would not affect their grades, but that it would delay completion of the learning tasks. A number of other incidents were observed which demonstrated the need for student self-regulation. For example, streaming video lecture displays are reset when an avatar hits the play button, disturbing other viewers. Also, in certain instances one student's simulation was too close to another's and the resulting interference disrupted the learning activity. Some avatars wore learning content and moved randomly, affecting others' learning.

Figure 1. Student content creation and content alteration in the learning environment

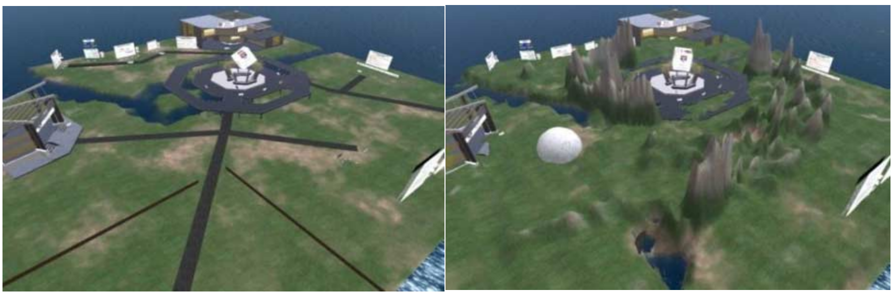

Figure 2. A region compared at the end of the session: left – original layout and right - the terrain modified and content altered region

4.1. Questionnaire and Analysis

Although students had different levels of the same learning task, both samples were similar with respect to the study measures, hence analysed as a single sample (n=59). Four questions were given to the students at the end of the learning sessions:

Q1: I think my behaviour affected others' learning

Q2: The open space and others avatars allowed me to interact as in a real-world learning session

Q3: Use of real identities increases proper behaviour of students

Q4: Students should use the learning environment responsibly

Likert scales ranging from 1-strongly disagree to 5-strongly agree were used; results are given in Table 1. Q1 is a self-assessing question as students had to think about their behaviour reflectively and critically. This was important to meet the objectives of the question set, as students answered the rest of the questions with a reflective mind on what they experienced or felt during their learning. Students may have been doubtful about the degree they consider their behaviour had impacted on others' learning; therefore, a mean of 3.31 (more towards the response "Neither Agree nor Disagree") while the majority confirming that (mode = 3) was observed. Questions Q2, Q3 and Q4 have recorded nearly the same means (~4 = Agree) while the majority confirms that preference (mode is 4 for each question). Q2 solicited privacy concerns of being in an open environment that could be seen by others and with a high probability of simultaneous engagement in the same learning activity or content. The association of the real-world classroom metaphor reinforces the student comparative observations, resulting in a broader opinion with higher accuracy. Q3 examines the student view on having their real identity (first name and last name) as their avatar username.

Table 1. Questions measured student self-regulation within OpenSim and descriptive statistics

#	Question	Mean	Mode	Std. Dev	Std. Err
1	I think my behaviour affected others' learning	3.31	3	0.592	.104
2	The open space and others avatars allowed me to interact as in a real-world learning session	4.05	4	0.354	.064
3	Use of real identities increases proper behaviour of students	4.02	4	0.309	.056
4	Students should use the learning environment responsibly	4.10	4	0.296	.051

Avatar anonymity and its impact on student learning has been researched previously in various contexts [15]; the majority of students agreed (mode = 4 & mean = 4.02) that there is a positive effect from using their real identities. Q4 elicits the student's reflection on being a responsible participant in the learning session. The responses indicated the majority of the students agreed that they must use the environment responsibly; a positive indication of self-regulated interaction as an acceptable practice.

An open ended discussion was carried out with each student after their learning session. Among the common responses such as learning was fun, flexible and easy, a notable response was that user support and training were needed to shape their interactions within OpenSim; it was indicated by 57.6% participants with similar expressions. This view was reinforced when some students justified their low self-regulation actions (such as in Fig. 1 and 2) as being due to a lack of knowledge about OpenSim functions and their effects; they claimed that had they been given a prior training and adequate support they would not have behaved in such manner.

Due to the nature of the research, the study sample was limited to a particular set of students. These students have provided their feedback and answers based on their experiences, which were validated through observation. The questions used were appropriately designed; they have yet to be examined for psychometric measures, partly because it is a challenge to find an accepted set of suitable measures as this field of study is still growing.

5. Conclusion

Virtual world based learning environments can be highly effective. A learner is represented by an avatar which interacts with, and explores, the environment, thereby creating a high degree of engagement and intrinsically achieving student-centred learning. However, one of the main assumptions behind the success of student-centred learning is self-regulation. This is particularly important in virtual worlds as the very freedom to explore and interact can also result in distraction from, and disruption to, intended learning outcomes. Yet locking down aspects of the environment to avoid these potential problems also reduces its attractiveness and basis for learner engagement.

This research carried out a study of the behaviour of 59 computer networking students using Wireless Island, a bespoke learning environment. It was found that in the absence of restrictive virtual world configurations some distraction and disruption did indeed take place, but when asked to reflect on their learning experience after the sessions most students agreed on the importance of self-regulation.

One of the main policy implications of this research is the need for suitable user support and training as a means for promoting student self-regulation. This need was further investigated and a specially designed set of OpenSim islands aiming at fulfilling different levels (introductory and advanced) of user training needs was later developed [20]; these training islands were evaluated for their efficacy for training with actual course modules and are now used as starting places for new OpenSim users. The research findings indicate that when learning in immersive environments such as OpenSim it is important to promote and maintain a high level of student self-regulation not only to achieve the intended learning outcomes but also to avoid disturbance to other students thereby supporting them in achieving their learning goals.

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What characteristics of the gamers'profile should be taken into account in player-centred game design?

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Abstract. In this paper, we introduce the theory of trait Emotional Intelligence ('trait EI') as a personality theory that could assist in exemplifying the gamers' profile and contribute to the design of player-center game experiences. Data from two studies (a game-specific and a game-general one) led to a number of player-centered playability principles that could inform the design of adaptable games and games targeting specific gaming audiences. The gamers' emotional characteristics were found to be of prominent importance to the design of good games.

Keywords. Player-centred design; Emotional Intelligence; nationality; gender

1. Introduction

A user-centered approach is recognized as fundamental when studying usability [1]. In this paper, we depart from traditional conceptions of usability measuring games' functional values, to examine usability in terms of playability and player-centered design. We introduce the theory of trait Emotional Intelligence ('trait EI') as a personality theory that could assist in exemplifying the gamers' profile and contribute to the design of player-center game experiences. Trait EI assesses individuals' self-perceived emotional characteristics and dispositions and as a personality trait was found to relate to well-being and life-satisfaction [2, 3]. Rather than examining the immediate emotional reactions of the gamers (see literature on affective gaming), we consider for their socio-emotional personality characteristics and how these might relate to certain game preferences (e.g., choice of certain games, nature of gameplay, in-game actions) in order to propose gamer-sensitive playability design principles. To this end, we also examined gamers' demographic characteristics specifically gender, age, nationality, and how these might relate to game preferences. The player-centered usability principles proposed in this paper emerged from the empirical examination of gaming in two instances: a) Study 1: A short-scale study examining general game use and b) Study 2: The gamers' use of a specific game - World of Warcraft (WoW). These

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principles contribute evidence to the design of adaptable games and games targeting specific gaming audiences.

2. Playability Guidelines

Traditional usability evaluations (e.g., ISO 9241-11) could only be applied to the case of gaming if games were viewed as regular software products. In the case of game design 'usability is not sufficient to achieve the optimum Player Experience' [4]. Considering that games directly relate to the experience of gaming (by producing feelings of fun and enjoyment) and game interaction, the concept of playability has been introduced to evaluate usability for games. Malone [5] was the first to introduce heuristics for designing enjoyable interfaces drawing from the example of computer games, including challenge (i.e., goal, uncertain outcome), fantasy, and curiosity (i.e., audiovisual effect, randomness, new information when previous knowledge is not adequate). Researchers [6] following Malone modeled the gamers' enjoyment using the dimensions of flow proposing four elements of playability: 1. Functional playability; how control mechanics relate to gameplay (e.g., controllers of video game consoles), 2. Structural playability; evaluation of the rules, structures and patterns of the product as well as the players' evaluation of the skills, experience and actions required for gameplay. 3. Audiovisual playability; the games' audiovisual style and appearance, and 4. Social playability; the games' potential/functionality to develop online communities, communicate social information and form diverse social relationships from antagonistic to romantic ones. Similarly, Sweetser and Wyeth [7] using the dimensions of flow and aspects of social interaction modeled the gamers' enjoyment and managed to distinguish between high and low-rated games. Febretti and Garzotto [8] made a distinction between the terms 'usability' and 'playability' and identified that playability factors such as social interaction, challenge, concentration, immersion, player ability, objectives, feedback, immersion, and control, foster or inhibit long-term game engagement (given that usability problems are few and easily overcome).

Although much emphasis has been given on producing playability principles drawing from theories of play, fun and enjoyment, less emphasis has been given on how the gamers and their actual gaming experience can inform usability and playability assessments. In general, playability heuristics resulted from the analysis of game-related theory and reports from game designers that led to the production of varied sets of game design features required for designing successful game experiences. A different methodological approach proposed by Fabricatore, Nussbaum, and Rosas [1] structured playability criteria based on the players' actual experience of gameplay (through game sessions) and gamers' preferences for play pointing to game aspects such as identity, energy, the player's view, transitions between scenarios, and complexity. Sketching the profile of end-users can contribute to designing more satisfying and personalised game experiences and thus cater gamers' individual characteristics more effectively.

Reviewing recent game demographics, it becomes evident that, alongside the traditional profile of the 'hardcore' gamer, casual gaming has come to the forefront [9]. The latest ESA report [10] points to a gender equality distribution with 56% of gamers being male and 44% female. The most frequent female gamer is on average 43 years old while the male gamer is aged 35. In addition, the top three types of games played are social games, action games and puzzle/board/card games. Moreover, almost half of the US population (more than 150 million) [10] and 44% of Europeans [11] are gaming. This demographic analysis indicates that gamers are not a homogenous population and motivates a closer examination of the gamers and their game practices to identify whether certain individual characteristics relate to gaming and can explain the above discrepancies. This understanding will contribute to designing more rewarding and satisfying gaming experiences after considering for the players' profile and their individual characteristics.

In an attempt to shed light on who the gamers are and how this knowledge might relate to gaming, we deployed the concept of trait Emotional Experience ('trait EI'). Trait EI refers to individuals' self-perceived emotion-related abilities and behaviour dispositions. It is a construct measuring emotional intelligence and its four components: a) Well-being – Individuals with high scores feel happiness, fulfilment, and well-being, b) Emotionality – Individuals with high scores believe they have a wide range of emotion-related skills that can use to develop and sustain close emotional relationships, c) Sociability – Individuals with high scores believe they can interact and communicate better within diverse social contexts (social influence and interaction in conditions other than family and personal relationships), and d) Self-control – Individuals with high scores believe they can control their urges and desires and regulate stress [3]. Trait EI has been positively associated to, for example, life satisfaction [2] and adaptive coping styles [3] while it is inversely associated to maladaptive styles [3, 2] and depression [12]. Individuals with lower scores on trait EI are more likely to experience 'personality disorders' [2]. The concept of trait EI has been deployed in this study due to its relationship to gamers' preferences for play and persistency of gaming [13, 14]. Game preferences were found to match with the gamers' trait EI indicating that gamers are more likely to choose game practices that accord with their personality characteristics.

3. Methodological Design and Results

To identify which of the gamers' characteristics are useful in player-centred usability design, we draw evidence from two studies: a) A short-scale survey (N=114) with mainly European gamers who play multiple genres of digital games. Specifically, 73.7% of gamers reported playing more than one type of games including action/adventure, strategy, role-playing, and casual/arcade games (e.g., Grand Theft Auto, Fifa, Diablo, Minecraft, Sims, WoW, Angry Birds, Solitaire). In terms of origin, 72.8% of gamers were European and 23% North American. This study was focused on examining gender issues (53.5% male; 45.6% female) (Mean age=30.8, SD=12.3), and b) A large scale survey (N=1042) with mainly male American (N=545, Male: 515) and European (N=497, Male: 487), 16-25 years old, high-end gamers (i.e., gamers who have reached the highest game level) of the game World of Warcraft (WoW). By being systematically involved in gaming, high-end gamers can illuminate the key design principles underlying long-term involvement in gaming and inform the design of games that reinforce persistent use. In both studies, gamers were found to game daily, 3 to 5 hours a day. Participants were self-selective, identified through online announcements of the two studies in popular gaming forums such as gamespot.com and reddit.com. Data for gender, age, ethnicity, trait EI, and game preferences/uses were collected in both studies. In Study 1, game preferences referred to frequently played games, location, frequency and duration of gaming, and reasons for gaming. In Study 2, game preferences referred to in-game choices as measured by Yee's Motivation of Play scale [16]. Yee categorised game preferences in MMORPGs into three clusters: achievement preferences (competition, advancement, game mechanisms), social (socializing, teamwork, relationships), and immersion preferences (exploration, role-playing, discovery, customization). The short version of the Trait Emotional Intelligence Questionnaire [TEIQue-SF; 15] was used to measure trait EI. The TEIQue-SF includes 30 items on a 7-point Likert scale. Descriptive and inferential statistics were used to analyze data and draw conclusions.

Study 1: Independent t-tests revealed no gender differences in terms of frequency and duration of gaming, location of gaming (home/on-the-go/at work) and trait EI, indicating that game preferences are rather similar between male and female gamers. In terms of the location of gaming, the great majority of participants prefer to game at home (83% of male and 69% of female; 27% of female game either on-the-go or both home and on-the-go). This evidence suggests that designing games specifically for women might not be of use due to similar profiles and patterns of use between male and female gamers. The qualitative, thematic analysis of the reasons for play indicated as the most frequently reported themes the following: a preference for flexible games with constant changes, storyline, multiplayer elements, quick/easy games and promotion of thinking skills.

An independent t-test revealed no gender differences in trait EI ($t=-.89$, $df=111$, $p=.370$, NS). On the contrary, a correlational analysis indicated that gamers with higher trait EI tended to game less hours per week ($r=-.311$, $p<.001$). Also, the older the gamer becomes the less hours on gaming were spent ($r=-.310$, $p<.001$). These patterns confirm previous published work [13] and raise the need for designing short and easily completed games to appeal to older gamers who spend less time on gaming.

Study 2: In terms of nationality, independent t-tests revealed no statistically significant differences in game frequency and duration of gaming between European and American gamers. Statistically significant differences were found in trait EI; American trait EI scores ($t=4.19$. $df= 1040$, $p <0.001$) ($M=4.92$, $SD=.85$) were higher than European ($M= 4.70$, $SD=.79$). In terms of game preferences as measured by Yee's Motivation of Play scale [16], American gamers with greater interest in achievement practices were found to have lower scores on global trait EI ($r = -.149$, $p <.001$), well-being ($r = -.115$, $p<.001$), self-control ($r =-.173$, $p<.001$) and emotionality ($r =-.162$, $p<.001$). No significant correlations for sociability were found ($r = -.006$, $p<.001$. NS). American gamers with greater interest in social practices presented higher scores in global trait EI ($r = .185$, $p<.001$), well-being ($r =.189$, $p<.001$), emotionality ($r =.224$, $p<.001$) and sociability ($r =.142$, $p<.001$). No significant correlations with self-control ($r =.067$, $p<.001$, NS) were found. The analysis of the preferences of European gamers revealed that achievement practices were negatively related to only emotionality ($r =-.130$, $p<.001$) while social practices were positively related to trait EI ($r =.119$, $p<.001$), well-being ($r=.088$, $p<.005$), and emotionality ($r = .158$, $p<.001$). No significant differences were found in immersive practices.

4. Conclusion

Two studies were conducted to identify which characteristics of the gamers' profile inform player-centered usability design. Nationality and emotion-related personality traits were found to relate to game preferences. Even though recent statistics point to the interest of gamers in social games and collaborative gameplay [10], there is still scepticism as to whether social interaction should be included in usability evaluations [17]. Our study stresses the need to bring to the forefront the social and emotional aspects of usability as a means to design enjoyable player-centered game experiences. This work places under scrutiny the validity of those HCI approaches generalizing usability principles and heuristics to the universe of gamers assuming that they comprise a homogenous population. Our findings strongly support the consideration of specific individual characteristics to the design of player-centred game experiences as follows:

4.1. Gender: The stereotype of the gamer as a male teenager no longer holds true as recent statistics [10] point to a gender equality distribution between adult male and female gamers. This gender distribution was confirmed in Study 1. In contrast, a male-dominant distribution was observed in Study 2 suggesting that game-specific examinations might produce a different understanding of gender issues in gaming and skew results if certain games are over-presented in a given piece of research. In addition, the failure to engage girls in gameplay when testing early game prototypes [23] and the assumption by some game designers that female gamers need special 'themes' to be attracted to gaming [24] led to the belief that 'female-friendly' games should be designed. Study 1 point to common patterns of game use between male and female gamers advocating the design of gender-free games. Specifically, both male and female gamers were found to be involved in various games, play frequently and persistently, both at home and on-the-go, and have similar emotion-related characteristics. Also, they game less frequently as they grow up and prefer easily-implemented, flexible, challenging games that integrate storyline elements and promote thinking skills. Similar patterns of gaming between male and female gamers are found elsewhere [27] including the perception of gaming as being integrated in everyday life and as an escape from reality, and social interaction and enjoyment as reasons for gameplay. What might prevent female gamers from playing specific games and perhaps explain the dearth of female gamers in games such as WoW, might relate to stereotypes in certain games such as epic struggles, violent and competitive content, and the presentation of female game characters as attractive, sexy, innocent or supplementary characters [25].

4.2. Nationality: Significant differences in trait EI and game preferences were found between Americans and Europeans. Gamers' preferences for play were found to be culturally bounded; American gamers were more interested in achievement practices, that is, gaming that involves competition with others and in-game advancement. On the contrary, European gamers were found to be more interested in social practices, including socializing, group work and the creation of emotional bonds. Immersive practices including role-playing, exploration, discovery and escapism are practices of general interest to gamers. These findings suggest that games should adapt to gamers' personality orientation by providing gameplay choices that satisfy both socially and achievement oriented gamers. Recent statistics [10, 11] point to a discrepancy between the percentages of American (50%) and European gamers involved in gaming (44%). These statistics may comprise an indication that the game market supports better the needs of the American gaming population by offering games designed for achievement and competition rather than collaboration and socializing.

4.2 Trait Emotional Intelligence: Trait EI was inversely related to the time spent on gaming indicating that individuals with higher emotional self-perceptions spend less time gaming. This might comprise an indication that greater self-control, emotional and social skills and wellness relate to less gaming. Although this finding might favour approaches perceiving gaming as an outlet to real-life dissatisfactions [see 18], the trait EI mean analysis indicates a relative high mean trait EI score (M=4.8/7, SD=.94), suggesting that this is less likely the case. In terms of trait EI, Americans were found to perceive themselves as having higher trait EI scores compared to Europeans. The within-groups analysis of trait EI scores confirmed previous studies on the role of trait EI in gaming [13], indicating that gamers' emotional characteristics should be considered when designing games. Both American and European gamers with higher scores on trait EI were found to be prone towards social practices. This is an indication that more emotionally satisfied individuals become interested in the social aspects of gaming including, socializing, group work and significant relationships. On the contrary, Americans with lower scores on trait EI were more interested in achievement practices. This was not the case for Europeans; gamers with lower scores on emotionality only, that is, self-perceptions on emotion-related skills and personal relationships, were found to be more interested in achievement practices. It is suggested that for Europeans, achievement practices are of less interest, with the exception of those gamers who perceive themselves as having a narrow range of emotion-related skills and less able to develop and sustain close emotional relationships.

These findings are in contrast to approaches that consider emotional evaluations as unrelated to the process of usability assessment [19, 20]. Following Norman [21, 22], what is indicated in this paper is that good game designs have to consider for the gamers' emotional characteristics. The socio-emotional aspects of human behaviour should not be neglected in usability procedures, since gamers are more likely to become immersed in gameplay when it presents such features that align well with their emotional characteristics and game preferences.

Bartle [26] analysing MMORPGs categorised gamers into: killers (gamers who provoke or impose to others), achievers (competitive gamers), explorers (exploring the game world and game mechanics), and socialisers (being interested in relationships and communication). This taxonomy applies to MMORPG players and virtual worlds only and not to any other type of games or online activities. As explained by Bartle [26] applying the taxonomy to other gamers, there is the risk of dismissing other types of gamers that might exist in different game genres. Yee [16] elaborated further on this work clustering gamers' preferences in MMORPGs into achievement, socializing, and immersion. This paper adds insight to gamers' taxonomies as described by Bartle and Yee. Specifically, Bartle's and Yee's socialisers are described as individuals high in emotional intelligence; they are emotionally and socially aware and look for game experiences where they can express these personality characteristics. Bartle's killers and achievers (Yee's achievers) are described as less emotionally and socially aware individuals who look for less social game experiences such as imposing and competing others. In accordance with Bartle [26], immersive preferences underlie both achievement and social practices and are therefore endorsed by gamers with different emotion-related personality characteristics. In contrast to Bartle's and Yee's genre-bounded categorization (explaining game uses for MMORPGs only), this paper offers a gamer-sensitive categorization drawing from personality theory.

One of the limitations of this work relates to the generalization of results. Findings could be generalised only within the game genres under examination. Specifically, examining a single game, findings from Study 2 could be generalized to the genre of MMORPGs, in particular multiplayer role-playing games with similar affordances as the game WoW. Also, the average age of the WoW gamer in this study (16-25 years old) differs from the mean age of the average gamer (35 for male and 43 for women) [10] suggesting that the identified relationships might not apply to the general population of gamers (e.g., older gamers) and/or gamers who are playing other types of games (e.g., mobile games). In addition, it could be argued that the highly social interactive environment of games such as WoW [28] might have skewed our results. Yet, other research has showed that despite the social focus of MMORPGs, gamers with diverse game preferences and personality types are found to customize those games to their own individual style of gameplay leading to, for example, the identification of individualised forms of gameplay within social games such as WoW [14]. In terms of Study 1, greater caution should be given in generalizing the results due to the small sample size. Study 1 provides indications of who the 'generic' gamer might be and raises the need for future and more in-depth examinations of how this generic profile might differ or relate to the profile of gamers who are dedicated to specific games.

Overall, the two samples of gamers under examination are rather distinct. With reference to Study 2, it could be argued that gamers are rather dedicated to a single game as evidenced by the large amount of time they spent on WoW and their long-term and persistent involvement with the game. With reference to Study 1, although gamers are found to spend similar amount of time on gaming as WoW gamers, they spend their time on a diverse set of games. This might comprise an indication that the design of the game (WoW) presents such characteristics and affordances that successfully engage different types of gamers (in terms of personality characteristics) and keep them immersed in gameplay for long. If we analyse the design of the game, it becomes evident that the game encompasses characteristics from diverse game genres such as battlegrounds and arenas (see action and shooter games), role-playing and exploration (see role-playing and sandbox games), mission-based gaming (see strategy games), and management and life simulation (see simulation games). This might explain why gamers with diverse emotional personality traits find themselves immersed in a single game; they can identify and engage with those game options that align well with their emotional characteristics.

In the literature, we often encounter a distinction between 'hardcore' or 'serious' gamers and 'casual' gamers. Hardcore gamers often refer to those gamers who are systematically involved in gaming activities, they often own specialised game equipment (consoles, laptops) and perceive themselves as being 'serious' gamers in contrast to other people who might play games casually on devices such as smart phones and tablets. The emotion-based categorization of gamers given in this paper and the identification that the gamers' emotional traits do matter and should be accounted when designing games were the outcomes of examining both 'hardcore' and 'casual' gamers. These findings suggest that, when it comes to game design, it is pivotal to account for the experience of gaming *per se* and how this is perceived by the gamers (is it enjoyable/fun/satisfying/boring/frustrating?). What hardcore and casual gamers share is that they are both enticed by gameplay and enjoy becoming immersed in it yet in different manners. Emotions are tightly related to gaming and as such they should not be left behind when designing entertaining or other games.

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An Overview of Capturing Live Experience with Virtual and Augmented Reality

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Abstract. In this paper, we review the use of virtual and augmented reality technologies for capture and externalization of tacit knowledge from complex activity in knowledge-intensive professions. We focus on technologies for converting experience hidden in activity with the aim to boost industry competitiveness, innovation, and facilitate learning on the job. As such types of knowledge and experience are difficult to capture and represent in traditional media, we explore emerging technology along two lines of investigation. First, we look at applications of virtual reality to then, second, focus on using sensors, augmented reality, and wearable technologies. We discuss existing and future applications of experience capturing with virtual and augmented reality technologies. This review provides a comprehensive overview for those interested in recording virtual, real, and augmented activities, methods for delivering the recorded data, and extracting knowledge.

Keywords. Virtual Reality, Augmented Reality, Wearables, Recording, Tacit Knowledge, Professional Development.

1. Introduction

Competence is a potential for action, and human activity is the process leading to competence development. To convert experience to knowledge and enable learning, the information relevant for a master level of performance (aka ‘theory’), traditionally, is separated from the immediate experience of competent action (aka ‘practice’). In the past key roles in this conversion have been held by skilled teachers using direct instruction as well as by authors producing media such as textbooks or instructional films, to name but a few. With technical advances and with growing access to wearables, however, new opportunities arise for capturing, sharing, and re-enactment that do not rely on strict separation of knowledge from its application, also giving more room to new roles in knowledge production beyond the specialist curator.

Capturing activity at the right level of abstraction, while still retaining all relevant detail is a complex task, not only from the technological point of view, as a significant part of the actual experience has to be subducted in the process. Conventional approaches such as video recording or screen capturing provide only limited points of view, significantly reducing the wealth of information available from direct experience as well as its immediacy and authenticity. These technologies map activities in the real world to flattened representations with limited affordances. Learning needs more than that: its feedback loop character requires an iterative cycle of invention, observation, reflection and action/revision [1]. The first two stages are concerned with how contextualized information is measured, captured, stored and relayed to the individual, whereas the last two create a pathway to judgment and decision making [2].Virtual Reality (VR) and Augmented Reality (AR) technologies provide perspectives that may help overcome present reductionist limitations by implementing more open loops.

VR simulates spaces, objects, humans, and activities that often reproduce a precise image of the reality [3]. AR increasingly accommodates innovative devices and technologies, while at the same time leveraging our understanding of human-computer symbiosis by enhancing sensory feedback and enabling interaction with augmented information based on actions in the physical world [4].

The objective of the work presented in this paper is to survey the state of the art and assess the potential for VR, AR, and wearable technologies to capture experience and deliver recorded data directly to the user, looking at whether and how well re-enactment of a recording allows re-living of experience. In order to fulfil this objective, we describe work conducted within research projects and commercial platforms, identifying issues and challenges and characterize the approaches taken so far to overcome them. Prior reviews of the state of the art in using VR and AR do not focus in depth on experience capturing but provide insight into their application in general, falling short of inspecting facilities and approaches required for recording. This review consolidates existing work from many sources and relates them in a framework for capturing experiences as an overview of the field.

The rest of this contribution is organized as follows. In Section 2, we provide a theoretical background of activity theory, tacit knowledge, and workplace learning. In addition, we introduce a characterization framework to structure the work. In section 3, we present an overview of the most representative examples of capturing *virtual* activities, while Section 4 presents a review of AR applications for capturing *real-life* activities and extracting knowledge from them. Section 5 then condenses findings in an overview and discusses the state of the field. Finally, in Section 6, we describe future challenges that require further work and research.

2. Experience Capturing and Knowledge Conversion

From an epistemological perspective, knowledge resides in and is accessible from community memory repositories. Knowledge appears in many forms. Tangible knowledge may be stored as written instructions or in databases. Intangible knowledge appears as activity, practice, relation between participants, and in their shared experience. The former type of knowledge is known as explicit and the latter as tacit [5]. In education and professional development, the two types of knowledge are mutually dependent and constituting [6, 7]. Tacit knowledge has been recognized to be important for industry competitiveness, innovation, and workplace learning [7].

Tacit knowledge can be converted to explicit knowledge through narratives – in addition to iterative training that aim to create embodied experience through activity. Capturing tacit knowledge from activity facilitates sharing and transfer, giving rise to new applications such as the accurate preservation of activity (also registering involved methods and procedures), retrospective analysis and reflection on action, and scripted re-enactment in related trainings [8].

Examples for rich experiences include safety training simulators, forensic recreation of crime scenes, task sharing from expert to novice at the workplace, or training of operation or maintenance of advanced machinery. Executing such activity typically requires specialist knowledge in a particular domain and a high level of skill to achieve a master level of performance. It is evident that capturing 'rich' experiences from such 'fluid' containers poses a significant challenge, not only to traditional repositories. Still, the knowledge they carry is essential for many high-skill professions [9]. Drawing upon the work in activity theory [10], we may see activity as a primary source for the development of knowledge from experience. As knowledge containers, activities can be characterized by their narratives, the collaboration, actors and objects involved, their governing rules, etc.

With respect to Virtual and Augmented Reality applications, there are several dimensions along which systems and approaches differ significantly from each other. We identify six such key dimensions: learning affordances, perspectives & viewpoints, levels of abstraction, editing facilities, social scope, and sensors & senses (Fig 1).

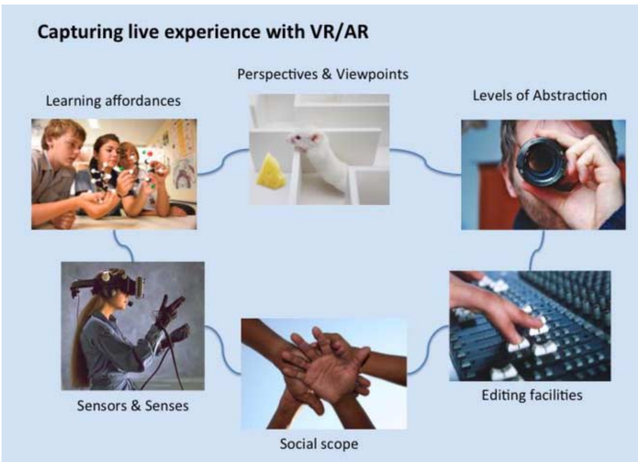

Figure 1. Dimensions for capturing VR/AR experiences

Learning affordances thereby refer to "the perceived possibilities for both thinking and doing", derived from interaction with tools or content [11]. When reviewing the state of the art in Section 3 and 4, we will highlight the difference between systems and approaches in what they afford, for example, whether users utilize them for assessment, reflection, rehearsal, guidance, regulation, or planning.

With *perspectives and viewpoints* we look closely at how much flexibility is foreseen for revisiting the recorded experience: is there support for free replay or of fixed sequences? Can roles be changed? What about visual aspects such as viewing angles or support for cut-out views, overlays, or explosion charts?

This is related to, but independent of the supported *levels of abstraction* of the recording, turning attention to the segue from unfiltered, sensor raw-data oriented recording towards more abstract representations such as activity descriptions or annotations. While any recording renders tacit knowledge from the observed activity to explicit knowledge available in the data captured, the degree to which the essence of it becomes salient differs from case to case.

Furthermore, we will look at what *editing facilities* are provided to support conversion between such different levels of abstraction. This relates to such questions such whether it is possible to remove, add, or modify an object or person in a recording.

Under *social scope*, we investigate whether systems and approaches are primarily collaborative or single-person (or both). Moreover, we look at how sharing takes place. Thereby, collaborative activity and practice sharing are of special interest, as they play a key role in activating explication of otherwise internal thoughts and routines.

Last, but not least, we analyze, what *sensors* are deployed and which *senses* monitored. This relates to the level of reality inspected, whether observation and capturing stays merely audio-visual – or goes beyond that by, for example, capturing well-being data or machine diagnostics. Re-immersing into captured experiences using a virtual, augmented, or mixed reality environment can trigger deep learning, especially when complemented with information that otherwise would not be directly observable.

3. Capturing Virtual Experiences

The realism of VR-based systems improved significantly with advances in computer graphics. Modern desktop-free human-computer interfaces increase value and transferability of virtual experiences, especially since human cognition is closely coupled to sensory-motoric experiences [12].

The potential of VR for capturing activities and extracting value from observing from multiple points of view and perspectives was acknowledged as early as in the late 90s. MASSIVE-3 supported a mechanism called 'temporal links', which overlaid recordings of prior and present activities [13]. The CAVE Research Network had an application called Vmail which supported recording of an avatar's gestures and audio together with the surrounding environment [14].

Another example is Asynchronous Virtual Classroom (AVC) aimed at solving the problem of time-sharing in distance learning. AVC allowed a group of students to watch a video image of a certain lecture, while software agents were playing additional participants [15]. The system is designed to provide collaborative experience, as the agents acted based on the scripts of previously recorded real-live student activities (questions, answers and annotations), which defined the level of abstraction. The learning affordances of AVC are awareness of discussions in previous iterations of the same lecture and therefore – social learning.

The N*Vector project developed a technology for overcoming time-zone differences using three approaches to support annotations for collaboration in VR. These approaches included: VR-annotator – an annotation tool that allows attaching 3D VR recordings to objects; VR-mail – an email system built to work entirely in VR; VR-vcr – a streaming recorder to record all transactions that occur in a collaborative session [16]. VR-vcr allows experiencing a virtual recording from multiple perspectives and points of view. Captured experience is composed of state updates of 3D objects and tracker data for the users. VR-mail was designed to work in a CAVE environment and supported gesture tracking and sound capture. VR-annotator supports text and sound notes attached to 3D objects – another level of abstraction.

More recently, an Event Recorder feature was implemented (though then not developed further) within the Project Wonderland (aka. Open Wonderland). The Event

Recorder implements capturing and playback of ‘events’ caused by activities of users and agents in such a way that during playback a user is able to view the activities that those events caused. 'Events' are recorded into an external form that can then be replayed to all the users in the space. A specialized plugin records the states and transitions of objects that cannot be represented as events (e.g., audio conversations).

vAcademia is a functional VR system that supports virtual recording [17]. This feature allows everything to be captured in a given virtual location including the state of objects and avatars, media contents, and text and voice communication. In addition, any recorded session can be attended by a group of users. A new group can work within a recorded session (with their avatars) and record it again making multi layered documentation capturing the evolution of an activity. A set of editing tools is provided such as cutting out parts on the timeline and modifying sound streams of users. vAcademia supports gesture tracking with Kinect and displays the environment on desktop or HMD (Oculus Rift). The learning affordances of vAcademia include collaborative review and analysis of captured collaborative experience.

4. Capturing Augmented Reality Experiences

The characteristics of AR [18] are strongly related with the senses of presence, immediacy, and immersion. The nature of AR provides a return to embodiment [19] that conditions the way users interact with their surrounding physical context. Analysts predict that we are on the verge of ubiquitously adopting AR to enhance our perception and help us see, hear, and feel in new and enriched ways [20]. Mobile technology is moving us from ‘information communication’ to ‘experience communication’[21].

The first technologies that were used to capture a physical contextualized experience enabled the use of AR tracking thanks to the sensors available in handheld devices. Motion capture is a way of effectively storing and re-enacting experience enabling stylistic analysis [22]. A more complete perception of the context implies being able to sense not only the contents of that environment but also to establish a perceptually correct connection between those real-world objects and digital content. This is currently achieved using sensor-based, vision-based and hybrid tracking [23].

‘Perceptual technologies’ [24] are capable of capturing users’ mental and physiologic states using bio-signals and physiological phenomena. In The Mind-Mirror [25], a combination of EEG and AR enables a 3D visualization of the subjects own brain activity. The Transformative Technology Lab (http://transtechlab.org) uses AR in biofeedback applications to capture and transform processes in minds and bodies of their subjects that can then be experienced externally. In some cases, this results in going beyond first-hand experience to social or collective experience. HearNow (http://www.biofluent.com/hearnow) is intended to focus attention for behavior change by converting brain and heart activity into ‘immersive soundscapes’ with the goal of increasing self-awareness and consciousness.

The ability within one field of view, to be both in the world and to see yourself in it [26] is an important tool for capturing live experience with AR. Field of view technologies (FOV), such as the FlyVIZ 360 headset, transform the real time visual system of users by giving them 360-degree vision compressed to fit into a 180 degree visor. It takes 15 min for the brain to adjust before this new way of seeing is ‘accepted as normal’ [27]. The AR-brain-machine interface (AR-BMI) enables a third-person view of the real environment by tele-operating an agent robot using brain signals [28].

AR is being adopted to create new sense modalities, 'perception beyond human senses' or 'sixth senses'. AR provides new perspectives and viewpoints, allowing a color blind person to capture and convert his experience of color (http://cyborgism.wix.com/cyborg). FeelSpace enables magnetic field sensing using a belt that produces vibro-tactile notifications (http://feelspace.cogsci.uni-osnabrueck.de).

Wearable sensing technologies allow a much closer association with the user and a higher degree of freedom. The wearable sees, hears and perceives the user's physical state. Wearable health-monitoring systems have drawn the attention of medical researchers and the industry. AR headsets are used to assist amputee victims with re-training the brain to recognize and integrate a fully working limb into its mind map.

The potential impact on industry competitiveness, innovation, and workplace learning is still emerging alongside the potential use cases. The concept of Interactive Augmented Prototyping combines virtual and physical prototypes for recording and recollection of design review meetings [29]. Novel editing tools support creating high-quality video tutorials for physical tasks using AR recording demonstrations [30]. Tangible AR interfaces enable intuitive manipulation and interaction with physical objects, and are expected to find use in product design, manufacturing, assembly, industrial processes and workplace instruction.

5. Summary

Using examples from our overview, we now attempt to summarize the features of VR and AR technologies which define the characteristics of the framework (Table 1).

Table 1. State of the art analysis against the dimensions of the experience capturing framework

VR	AR
Learning affordances	
The learning affordances related to captured experience are reflection, analysis and assessment. These are thoroughly supported in packages such as vAcademia and can be recorded repeatedly resulting in both an original experience and the review experience in a single recording. Pre-recorded experience can be used as background for life actions.	AR has compelling educational and pedagogical implications, providing a medium for understanding concepts and phenomena by integrating physical and digital worlds. Learning affordances include developing skills in context, tangible manipulation and exploration, improved immersion, ubiquitous and situated learning, and facilitation of social and collaborative learning tasks.
Perspectives & Viewpoints	
Most of the existing VR systems allow generation and use of multiple perspectives and viewpoints. The recorded experience can be observed from any point of view in the virtual space. An additional role of a reviewer is common, except for systems such as AVC which support only one role in both live and recorded experience. Most of the VR systems supply free reply functionality, allowing any additional actions during re-enactment. AVC stands out as having a fixed sequence of actions (timeline), while previously captured experience overlays over the live experience.	The combination of FOV technologies, see-through displays, third-person view and ambient-awareness are radically evolving this characteristic of the framework. AR enables wearable context awareness, and a number of self-awareness / self-observation AR systems are being developed (e.g. The Mind-Mirror). Some striking results of this characteristic are enabling perceptual awareness both from inside and outside the anatomy of the human body (e.g., AR-BMI) and the ability for us to create entirely new senses (feelSpace).
Levels of Abstraction	
Various levels of abstraction are used for capturing experience in VR systems. Sensor data is captured in some VR systems (e.g., N*Vector and vAcademia) to be re-enacted in virtual simulation. Such simulation	In AR, tangible objects act as triggers representing concepts and their interrelationships. This aspect opens a broad range of interpretations within the context of a reality-virtuality continuum. AR has a

can copy the reality – close to raw data. It can also be different – high level of abstraction. For example, AVC represents experiences as activity scripts. Most systems support text, sound or graphical annotations (e.g., AVC, N*Vector/VR-annotator and vAcademia).	powerful potential of creating new body - brain maps associations (Cyborg Foundation), extend sensing capabilities (feelSpace), and reshape and transform the perception of the surrounding physical context and our own body (HearNow).
Editing facilities	
Most VR systems provide control over the re-enactment (e.g., fast-forwarding). However, facilities for editing captured VR experience are not common. vAcademia supports cutting out parts of the recorded experience on the timeline, performing new activities with the addition of scripted objects while re-enacting, and removing/modifying sound streams of the recorded users.	Although still in its early stages, AR is a potentially powerful paradigm for annotating and editing the environment as well as our mental and physical states. Democut supports creating effective tutorials for physical tasks using AR recordings and enabling audio and video analysis, automatic organization, user annotations and video editing effects.
Social Scope	
In the past, VR systems allowed single-user re-enactment of experience (N*Vector, VR-mail and CAVE Research Network, Vmail). MASSIVE-3, AVC, vAcademia, and Wonderland allow collaborative observation of re-enactments by the same or other users. Observation of pre-recorded experiences can create an impression that these experiences are live during the re-enactment – a pseudo-collaborative experience.	AR tangible and enhanced experience represents a step forward into shared experience and collective communication. The third-person view encourages the ability to go beyond first-hand experience to collective identity. The Transformative Technology Lab uses biofeedback to create contextual embodiment and collective consciousness. These features enable previously unknown levels of collective insight and social collaboration.

6. Conclusion and Outlook

Although the study of capturing live experience with VR and AR technologies is still in its infancy, the advances and innovations over recent years direct us towards new possibilities for practical applications. Creating and applying a characterization framework, we identified the key properties of past and existing experience capturing systems. Features that implement experience capturing and re-enactment are summarized in section five against the dimensions of the framework.

Features for some of the dimensions are yet to be implemented. In VR-based experience capturing, sensing can advance beyond motion tracking and voice capturing. As the level of abstraction can be controlled more easily than in AR, this criterion can be experimented upon. In AR-based experience capturing, the sensing component has advanced recently but not all the senses can be captured and re-experienced (e.g., haptics). The level of abstraction can be developed up to and including holographic representation. The perspectives and viewpoints lack peripheral vision.

Both VR and AR technologies are used in a variety of professions. Repetition of certain procedures in a safe (VR-based) environment and practicing under supervision of (AR-based) assistance are well explored and used techniques. Experience capturing and re-enactment allows additional techniques such as self-observation, review, and analysis of experience with some flexibility along the dimensions of our framework.

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An Expert Review of REVERIE and its potential for game-based learning

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Abstract. REVERIE (REal and Virtual Engagement in Realistic Immersive Environments) is a research project with the aim to build a safe, collaborative, online environment which brings together realistic inter-personal communication and interaction. The REVERIE platform integrates cutting-edge technologies and tools, such as social networking services, spatial audio adaptation techniques, tools for creating personalized lookalike avatars, and artificial intelligence (A.I) detection features of the user's affective state into two distinct use cases. The first shows how REVERIE can be used in educational environments with an emphasis on social networking and learning. The second aims to emulate the look and feel of real physical presence and interaction for entertainment and collaborative purposes. This paper presents an expert evaluation of the first use case by potential users of REVERIE (teachers and students). Finally, the potential of REVERIE for game-based learning is discussed followed by an overview of the actionable recommendations that emerged as a result of the expert review.

Keywords. avatars, virtual human interaction, 3D audio and visual content, expert evaluation, game-based learning

1. Introduction

Social media is gradually finding its way into the educational sector. According to an annual survey done by Pearson Learning Solutions [1] the use of social media in classrooms increased by 21.3 % in 2013 compared to 2012. The most used social media methods are blogs and wikis but other platforms such as Facebook and Twitter increased in use from 2012 to 2013. Most educators agree that the interactive nature of e-learning and mobile technologies increase the teacher and student communication. But to date, learning on social media and other e-learning platforms has been a poor substitute for classroom learning. To address this issue a number of academic institutions have introduced *blended* [2] and *flipped* [3] learning strategies. In the former classroom strategy, students learn through a "blended" model of in-person (with a teacher) and technology-based instruction with some student control over time, place path and/or pace of the curriculum. For example, in a blended learning course, students might have face-to-face instruction by a teacher in a traditional classroom setting, while

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also independently engage with online materials of the course, created by the same instructor outside of the classroom. In a flipped classroom model, students gain the necessary knowledge before class, typically through the use of educational technology such as online videos, and during class time they explore that knowledge in greater depth through various methods including discussions, project-based learning and laboratory experiments guided by a teacher. In an effort to motivate and engage students in these new “hybrid” environments, instructors have recently started introducing game-based learning experiences as part of the learning process in the classroom as well as part of the online instructional materials. These serious games combine engaging gameplay with instruction designed to achieve specific educational or behavioural goals [4]. Class Craft for example [5], is an online role-playing video game that is been actively used in teaching a wide variety of subjects in schools. The game provides a gamification layer on top of any existing curriculum by teaching students personal and social skills in the classroom (e.g., the value of cooperation and hard work) and the idea that learning can be fun. Each student takes the role of a character (e.g., healer or warrior) and works to earn points and unlock special abilities. The teacher assumes the role of gameplay master and manages the gameplay experience in the classroom. Students can earn points to use in the game (e.g., to level up and gain powers) based on their behaviour in the class (e.g., by being positive and hard-working or answering a question correctly in the class). In the same way, disrupting class behaviour (e.g., showing up late to class or not turning in homework assignments) can lead to deduction of points. State-of-the-art learning content management systems (LCMS) such as ALICE [6], offer serious games as part of the online instructional material managed by the underlying platform. Instructors using the available platform tools can create unlimited training scenarios in the area of civil defence and in particular, building evacuation for use in blended or flipped learning experiences. However, none of these learning approaches can effectively work for geographically separated students. To bring the benefits of real-classroom experiences online to those students there is a need for a framework that introduces full multimodal communication between learners and their teachers. REVERIE (REal and Virtual Engagement in Realistic Immersive Environments) is a communication framework designed to address the increasing demand for realistic interpersonal online communication. The platform integrates state-of-the-art technologies in areas such as, spatial sound processing, autonomous avatars, acquisition of 3D data and processing, networking and emotional engagement in virtual worlds. These are combined into two use cases of which the educational one, is the focus of this paper.

2. Immersive Learning in Social Environments

REVERIE’s educational use case (UC1) has two scenarios. The first scenario is an assisted educational virtual excursion to the Brussels EU Parliament. It involves one teacher, one autonomous guide agent who has the role of a virtual guide and a group of students. Both the teacher and students are registered members of the TrueTube social educational network[2] that gives them automatic access to the REVERIE platform. The teacher creates a group on TrueTube, to invite the students he wants and gives them instructions on how to use the REVERIE platform. To access the virtual parliament,

[2] http://www.truetube.co.uk/

students and the teacher are given the choice to select a default virtual representation\avatar from REVERIE's standard library or to create a custom one using an avatar authoring tool (RAAT) [7]. The teacher chooses to access the parliament with a default avatar while the students with their own custom avatars impersonating their appearance. Avatars (standard or custom) can also reflect the participants' facial expressions, captured in real-time by the web camera. Once the teacher and students have entered the virtual scene (see Figure 1), the scenario starts with an autonomous tour guide agent guiding the students in an exploratory tour of major areas of the parliament. The teacher is in control when to start the tour. The agent asks the teacher if he's ready to start and the teacher can give positive reply with a head nod at his webcam or a "yes" vocal reply through his microphone. Destinations to the participants' semi-autonomous avatars are given automatically by REVERIE during a tour in order to follow the agent throughout the tour. Participants can choose to navigate away from the group, but always within the boundaries of the virtual scene. The participants' attention and emotional status is analyzed throughout the tour and the agent responds to those observations accordingly (e.g., by trying to get a student's attention if that was lost). The autonomous agent exhibits a range of pre-scripted body and facial behaviors (e.g., clapping, waving, happy and angry expressions) in synchrony with her speech. The tour ends with the agent asking participants to take a seat in the front row of the parliament and explaining the process of the debate. In particular, students have to present their views (with arguments for and/or against) on the topic of multiculturalism to their fellow students who can state their agreement or disagreement using REVERIE's voting feature. To get students into the context of the topic, the teacher s decides to share a relevant video with all of his students. The video streams in real-time over the Internet to all of the students' computers. Once the video finish playing the teacher decides which student should present first. The student walks to the lectern at the center of the parliament and enter the topic of the presentation on REVERIE's GUI (at the top of the screen). After the student has completed the presentation, the teacher can give the floor to the audience for questions and comments. Students may request to speak by raising their avatar's hand. Apart from the avatar's animation, the teacher's GUI menu is also updated to notify him that a student has requested to speak. The teacher may select to give the floor to the particular student by activating his/her audio, but he may also choose to ignore the request (e.g., if the student has a disrupting behavior).

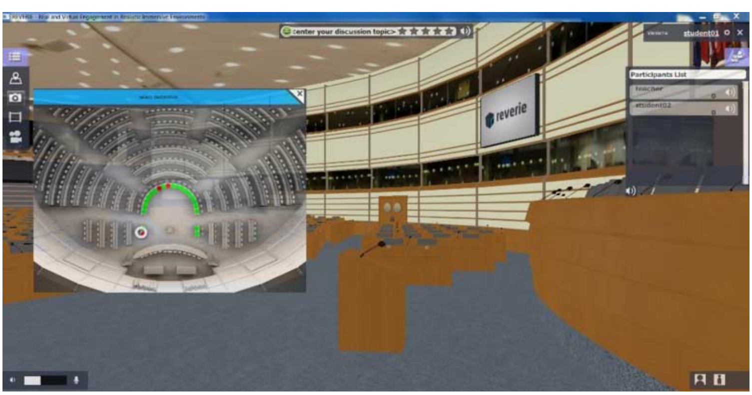

Figure 1. A screenshot of the virtual EU Parliament in REVERIE.

Once all questions/comments are completed, students are requested to vote about the presentation on a 5 point-scale (with 1 being the lowest and 5 the highest). Students can also take snapshots and record a session on video to share on social networking web sites such as Facebook and Twitter. After all students have presented their views on the topic, the session ends with the teacher announcing the student with the highest vote count as the winner of the debate. Participants may then choose to play a different scenario or to exit the REVERIE platform. When exiting this scenario the group is automatically led to the exit door of the parliament where the agent runs a goodbye animation.

The second educational scenario is a virtual gallery with 3D reconstructed objects (see Figure 2) representing various historical eras. This scenario is a virtual gallery competition, where students have to search the virtual gallery, find objects assigned by the teacher and talk about them with the aim to convince their fellow students and teacher about the importance of the object. Specifically, once they are all in the virtual gallery, the teacher shares with each student a card containing information and a number of questions to consider in their presentations (e.g., when was the object made, why is it important?) about a random object in the gallery. The student has to walk around the world, closely observe the exhibits in order to find the object. Once the student finds the object, s/he needs to guide the rest of the group by providing navigation instructions using the spatial audio features around the object so the presentation can begin. Once the student is ready, s/he must enter the name of the object on the REVERIE GUI and start presenting.

Figure2. A screenshot of the virtual gallery in REVERIE.

Once the presentation is completed, the rest of the group votes on the quality of the presentation using a 5 point scale (with 1 being the lowest and 5 the highest mark). When all students have presented their object and voted on each other, the teacher announces the student with the highest total votes as the winner of the competition.

3. An expert evaluation of the immersive learning scenarios

A formal usability inspection was done of the two immersive learning scenarios using the Cognitive Walkthrough method [8]. The Cognitive Walkthrough (CW) uses an explicitly detailed procedure to simulate a user's problem-solving steps in tasks they can perform with the system. The process starts with an analysis of the required tasks, where the experimenter specifies a sequence of actions required by the user to complete the task, and the system response(s) to those actions. The experts' walk-through the steps, asking themselves the following questions: (a) Will the user realistically trying to do this action? (b) Is the control of the action visible? (c) Is there a strong link between the control and action? (d) Is the feedback given by the system appropriate? Below the input to the cognitive walkthrough for the educational use case is defined:

3.1. Who are the experts who reviewed the immersive learning scenarios

In total, nine experts reviewed the educational scenarios of REVERIE's UC1. A pilot evaluation was conducted with three experts to test the design our approach. Experts completed the same tasks as the rest of the experts, but spent more time in the lab than other users. They provided valuable feedback on the process followed and identified a number of technical problems with the prototype that were corrected in the lab. Feedback from this activity and guidelines found in the literature [9], led to the simplification of the standardized cognitive procedure that was eventually used in the evaluation of both scenarios. The first group of the main study included three experts (see expert 1 to expert 3 in Table 1) with a variety of technical and media backgrounds. They were asked to review:

- Tasks related to the integration of the REVERIE platform with Facebook, TrueTube and REVERIE social network to ensure maximum usability
- The RAAT tool, to ensure its usability. RAAT is REVERIE's integrated tool that allows users to fully customize their avatars before accessing any of REVERIE's virtual worlds. The version of the tool that was reviewed by the experts is available online (see [7]).
- The virtual 3D gallery competition scenario of UC1.

Table 1. The group of experts who reviewed the two immersive learning scenarios

Experts	Profile	Role	UC1 Scenario
Expert 1	Media Producer	Teacher	Scenario 1
Expert 2	Media Producer	Student	Scenario 1
Expert 3	Media Producer	Student	Scenario 1
Expert 4	Teacher	Teacher	Scenario 2
Expert 5	Office Assistant	Student	Scenario 2
Expert 6	Marketing/Research assistant	Student	Scenario 2

Each expert was asked to role play one of REVERIE's typical users based on a given persona and within the context of a given scenario of use. The personas illustrate typical REVERIE users according to the requirements of each use case. The personas that were used in the educational scenarios illustrate the profile of a teacher and two students and were used by both groups of experts. The scenario for UC1 provided a typical use case situation for the personas and it was done to contextualize the experience for the experts. Then, experts had to walk-through the action sequences for each task from the perspective of each user and within the context of the specific scenario.

The second group of experts (see expert 4 to expert 6 in Table 1) reviewed the *"Interactive Guided Tour and Debate in EU Parliament"* scenario. The set-up of this Cognitive Walkthrough was the same as above. Three experts role played the same personas (i.e., one teacher and two students), reviewed the tasks involved in this scenario. As the tasks involved in this use case scenario were more complex and longer to complete than those completed by the previous group, the second group of experts did not review any other activities. The analysis resulted into 48 actionable recommendations for both scenarios of REVERIE's UC1. From those we chose only 15 recommendations based on their importance for the successful completion of the project [10] and with a high educational and/or gamification impact value. This value signifies the potential impact (high, medium or low) of a recommendation when implemented to the educational and gamification value of REVERIE UC1 scenarios. An in-depth explanation of each recommendation can be found in [10] using the assigned unique identification numbers.

1. *User Authentication Services – Social Networking Integration*

Requirements	ID	Potential Education Impact	Potential Gamification Impact
Automatically import all student groups from TrueTube and allow Teachers to choose the groups (and students) they want to invite on the platform.	3	HIGH	LOW
Integrate a social media sharing functionality within REVERIE.	24	MEDIUM	HIGH
On the REVERIE desktop platform ensure proper feedback is provided as a result of the user's login action.	6	HIGH	LOW
During account validation (Facebook or TrueTube) redirect users to the relevant web sites without the need to enter any credentials.	2	LOW	LOW
Ensure clarity, consistency and relevance of the user's account menu bar on the REVERIE portal, for to each type of user (student/teacher).	4	MEDIUM	LOW

2. *General GUI Functionality*

Requirements	ID	Potential Education Impact	Potential Gamification Impact
Provide detailed information for each scenario to aid the user's selection.	7	HIGH	MEDIUM
Every time an asset loads in the RAAT tool a loading text should appear in the middle of the screen.	9	MEDIUM	MEDIUM
Provide clear instructions how users can access a selected scenario.	11	HIGH	LOW
Provide a toolbar button for users to change their point of view (POV).	18	MEDIUM	HIGH

3. Avatars

Requirements	ID	Potential Education Impact	Potential Gamification Impact
All users (teachers and students) should be able to see the output of the real-time avatar facial pappeting on demand.	34	MEDIUM	HIGH
Basic information about the participants to the virtual interaction should be provided by default, giving the possibility to hide it.	57	LOW	HIGH

4. 3D Virtual Scene Characteristics and Functionality

Requirements	ID	Potential Education Impact	Potential Gamification Impact
Revisit the design of the autonomous tour guide agent to improve its educational impact.	17	HIGH	HIGH
Provide a bird-eye view for teachers to be able to see where their students are in the parliament.	19	HIGH	MEDIUM

5. User-user and user-agent specific virtual interaction features

Requirements	ID	Potential Education Impact	Potential Gamification Impact
Teachers should be able to moderate a rating before it becomes publicly accessible and recorded on REVERIE.	23	HIGH	MEDIUM
Give teachers the option to speak to students in private.	22	HIGH	LOW

It is evident from the above, that REVERIE already has several gamification features with educational value that can be improved. The recommendation with ID 17 for example, *"Revisit the design of the autonomous tour guide agent to improve its educational impact"* clearly shows that a number of simple design interventions to the virtual tour guide agent would have a high impact on both the educational and gamification impact of the platform.

4. Conclusions and Future Work

In this paper, we presented REVERIE's educational use case (UC1). This use case is consisted of two educational scenarios: (a) an Interactive Tour and Debate in the Parliament and (b) a virtual gallery competition. It shows how the REVERIE framework can be used in educational environments with an emphasis on social networking and learning. This use case integrates social networking services, tools for creating personalised lookalike avatars, spatial audio techniques and Artificial Intelligence (A.I) on a single platform. The use case was evaluated by experts in a cognitive walkthrough. The results of the analysis were used to develop a series of actionable recommendations for future improvements to UC1 prototypes. The recommendations that were deemed as important are presented above clustered into five categories which also identify the directions for future development of REVERIE's UC1 prototypes: (1) User authentication – Social networking integration, (2) General GUI menu functionality, (3) Avatar Virtual Representation, (4) 3D virtual scene characteristics and functionality, and (5) user-to-user and user-to-agent specific virtual interaction features. Two patterns emerge from the evaluation activities reported in this paper. First, that REVERIE UC1 has a good potential to support game-based learning but more work should be done to maximise the impact of its gamification and educational features. Second, REVERIE's UC1 lacks several of the standard game mechanics found in video games and gamified applications (e.g., PBLs (points, badges, and leaderboards)). Therefore, a potential avenue for future research is to analyse REVERIE based on the Octalysis gamification framework [11] and add relevant game mechanics as necessary to maximize the educational and gamification value of the platform.

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Designing for User Engagement in Wearable-technology Enhanced Learning for Healthy Ageing

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Abstract. Today's demographic changes with the rising number of the elderly require new forms of health promotion and innovative approaches to increasing physical fitness. Physical activity is considered as one of the key factors of ageing healthy and at the same time one of the key motivational challenges for the elderly. Supporting healthy ageing through sustained physical fitness requires interventions that promote healthy levels of physical activity as part of everyday life. Wearable devices, such as activity trackers or smart wristbands, are body-worn and may be seamlessly integrated into everyday activities to track fitness data, thus bearing the potential of supporting healthy living habits at older age. Although wearable technologies have been used by younger adopters to optimise physical fitness, little is known so far how these emerging technologies may be leveraged to improve well-being and overall fitness of seniors. In this paper we present the multi-layer approach to designing for user user engagement in wearable-technology enhanced learning for healthy ageing as part of an R&D project called "Fitness MOOC - interaction of seniors with wearable fitness trackers in the MOOC (fMOOC)". fMOOC is a wearable-technology enhanced learning solution combining the MOOC (Massive Open Online Course) approach with embodied learning experience enhanced by wearable activity trackers used to track and monitor physical activity of senior learners. The paper proposes an adaptation of a standard User Experience (UX) model to the context of learning and instructional design and describes how methods for user engagement design have been applied on five different levels, i.e. conceptual, requirements, instructional, architecture and interface design, in the fMOOC project.

Keywords. Wearables, Wearable-technology enhanced learning, User Engagement, User Experience, MOOC

1. Introduction

Mobile health (mHealth) has been considered as one of the biggest technology breakthroughs of our time [21]. According to recent studies the percentage of adults in the USA tracking fitness data through a smartphone has grown approximately 100 percent during the last two years [25]. With wearable technologies becoming more widespread - in 2014 about 21% of US consumers already owned a wearable technology product [20], wearable devices and services are beginning to enhance the mHealth trend. Whilst wearable health and fitness technologies such as activity or fitness trackers (e.g. Jawbone, Fitbit, Nike, Garmin) have been used by younger audiences to measure and improve physical fitness, little is known so far about how senior users interact with wearable devices and which approaches may be effective for sustained user engagement of this user group. Recent studies point out that most wearable fitness devices fail to drive long-term sustained engagement for a majority of users independent of age [13], [14], [24]. Some of the key factors impeding user engagement are considered to be (a) limited functionalities (e.g. currently available fitness trackers provide only basic health metrics such as steps taken and calories burnt), (b) missing activity triggers (e.g. activity trackers capture data but do not inspire action), and (c) unclear utility (e.g. lack of clear purpose and benefits from long-term use). Also missing mechanisms for social interaction, goal reinforcement, contextual intelligence, bio-sensing, healthcare and digital health ecosystem integration, seamless interoperability, have been discussed as possible reasons for wearable devices and services not providing a significant impact on fitness habits yet [14], [20], [25]. One of the key research questions in this area is thus how wearable fitness technologies may be used to ensure sustained physical activity and practice as part of the daily routine, enhancing habit formation and making a long-term impact on users' health and well-being [13]. In this paper we present a novel approach for designing for user engagement as part of wearable-technology enhanced learning solution with the aim of promoting sustained engagement of senior users for healthy ageing.

2. Wearable-technology enhanced learning

Wearable-technology Enhanced Learning (WELL) is beginning to emerge as one of the earmarks of the transition from the desktop age through the mobile age to the age of wearable, ubiquitous computing [4]. While mobile devices are carried to a location and used in a state of temporal stationarity (e.g. standing, sitting), wearable, body-worn devices are used when the user is moving or engaging in other tasks (e.g. running, riding) [3]. In consequence mobile learning and wearable learning may be differentiated by (a) the type of physical activity of the learner, and (b) the type of physical fixture of the device. While mobile learning may require the learner to take a state of temporal stationarity and a device used for learning is not attached to the body of the learner, wearable learning is possible in the state of physical activity and the device is body-worn. Consequently, wearable-technology enhanced learning can be defined as learning in a state of physical mobility with support of devices which are body-worn [5].

In line with the current usage patterns of digital technologies forming the backdrop of personal communications [3], wearable-technology enhanced learning is enabled by connected, portable devices and digital media accessible on these devices, all forming extended Personal Learning Environments [7]. The development of wearable devices, such as smart wristbands, smart glasses, smart watches, smart gloves or even smart balls, drives the development of new scenarios and opportunities for learning, which may harness (a) contextual information by delivering and capturing personalised, instant and context specific information, (b) contextual interaction by bringing multiple, spatially distributed learners together; and (c) contextual participation by triggering opportunities for personal learning in a given context [5].

Wearable-technology enhanced learning may enhance embodied learning experience. While computer-mediated communication has been observed to enhance conscious experiences without self-reference leading to the sense of disembodiment, wearable technologies enhance embodied experience with a strong self-reference [26]. The concept of embodiment is based on the assumption that thoughts, feelings, and behaviours are grounded in bodily interaction with the environment [18]. Embodiment through wearable devices is enabled by gathering and transmitting bodily information onto a physical dynamic display, making this information accessible to others and extending the sensorial experience [27].

Although wearable devices have limited multimodal interfaces they can act as clients to embedded services [3]. Connected services and devices equipped with mechanisms for context and location awareness, activity tracking, monitoring and sharing of data, multimedia information capture and multiple communication channels, open new opportunities for learning, interaction and enhancing healthy living. In view of research results showing that even 30 minutes of daily moderate-intensity physical activity may significantly reduce the risk of chronic diseases [24], wearable technologies combined with possibilities for learning and social interaction may play an important role in health promotion. While wearable devices seem to appeal to younger and middle-age users, little is known about how seniors interact with wearables. One of the key challenges in designing wearable-technology enhanced learning for healthy ageing is the design for user engagement of senior users age 65 and over.

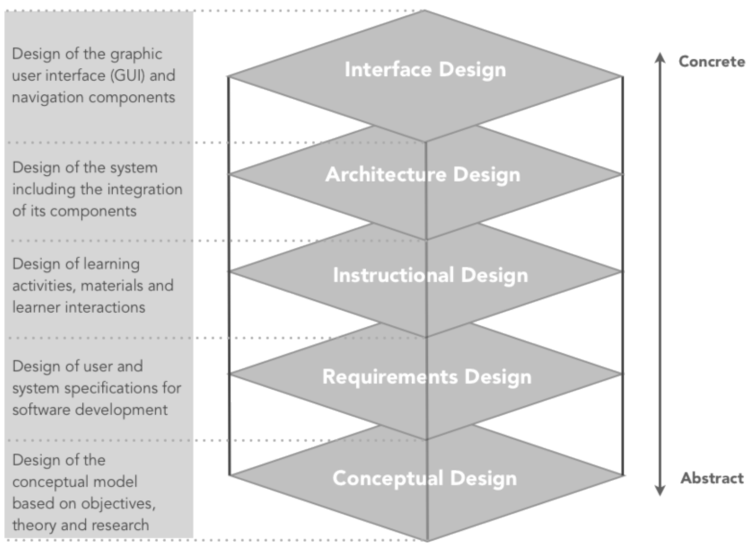

Figure 1. The multi-layer user engagement design in fMOOC

3. User Engagement Design

User engagement (UE) may be defined as the quality of the user experience (UX) that emphasises the positive aspects of the interaction, such as being captivated and motivated to use technologies [10], [12], [16]. Designing for user engagement for technology enhanced learning means designing engaging learning experiences, which may be evaluated by applying engagement metrics such as time spent on site, performed learning activities, number of comments. User engagement has been associated with specific user characteristics which can be also applied to the field of learning, e.g. focused attention, sense of control, novel and unexpected experience, positive emotions during the interaction, willingness to repeat the experience [1]. UE as the subset of UX draws on psychological theories, such as affect, arousal, engagement and flow [10]. In this section we describe multi-layer user engagement design in the fMOOC project based on the model of user experience proposed by [9], which has been adapted to the field of technology-enhanced learning and consequently includes the layer of instructional design (Figure 1). The design of user engagement takes place on all five layers as the elements affect each other to provide the overall user experience [9].

3.1. Conceptual design

The conceptual design of the fMOOC combines health, learning and technology as three distinctive research fields in the interdisciplinary approach to wearable-technology enhanced learning for healthy ageing. The central objective of fMOOC is promoting health and healthy ageing. Health is viewed as a dynamic state of well-being [2] and a set of learnable capabilities, i.e. a person can develop capabilities to live healthy, e.g. learning how to enhance physical fitness, learning how to deal with stress [13]. Healthy ageing is conceptualised as the process of optimising physical, social and mental health with the aim of active participation and enjoyment of independent and good quality life. Using wearables to promote health is conceptually embedded in geriatric research which has revealed positive effect of community-based interventions on improved ratings of physical health, reduced medication use, improved social interactions, less loneliness and fewer health problems [8]. The conceptual design in fMOOC links health and healthy ageing to motivation and health resilience, i.e. the capacity to maintain good health [22], as well as to the promotion of the sense of control, which has been shown to have a positive impact on health [8]. This again is conceptually related to the TEL approach called Personal Learning Environments (PLE) which emphasises a shift towards a greater learner control in technology-enhanced learning settings [6]. The key implications for designing user engagement in WELL for healthy ageing on the conceptual level are:

- helping seniors to remain resilient and motivated to engage in physical activities,
- focusing on personal abilities and resources for self-efficacy and self-esteem,
- strengthening determination for health resilience and coping with difficulties,
- enhancing community-based activities and social learning practice.
- recognising progress for the sense of mastery and the feeling of empowerment,
- enhancing social engagement for the feeling of comfort and the sense of belonging.

The conceptual design of the fMOOC is based on the concept of extended Personal Learning Environments (eX-PLE) in sense of permeable physical and virtual spaces, which are constructed dynamically through the practice of “mobility” across spaces, contexts, concepts and time as proposed by [7]. This approach combines a blended learning approach in sense of convergence of online and face-to-face experience with learning in a hybrid learning environment, in which several learning technologies, e.g. wearable, mobile and desktop technologies, are combined to form a seamless learning experience.

3.2. Requirements design

In order to design for user engagement in wearable-technology enhanced learning settings, the fMOOC development has been based on theoretical and empirical analysis of the needs of senior users. In general, user requirements in the fMOOC encompass needs related to hardware and the needs related to software design. The requirements engineering process in fMOOC includes the elicitation, the specification and the design phase of senior user requirements. On the software level, user requirements have been elicited in pre-tests and prioritised during the specification phase according to the agile software development, SCRUM methodology. These requirements were designed in form of use cases and user stories. Figure 2 shows example user stories which capture what users want to do in the fMOOC. User stories are prioritised and reviewed in the process of software development.

Number	Product backlog	Sprint
111	As a user I want to link my Garmin account with the fMOOC account to share my fitness data.	5
170	As a user I want to sync my data from the fitness tracker to monitor my progress.	5
112	As a user I want to choose an exercise on a particular week day.	8
149	As a user I want to view the ratings of other users of the exercise to decide which exercise to choose.	8
146	As a user I want to use the fMOOC app to guide my training plan during the week.	3
148	As a user I want to adjust my training plans on different week days to be flexible in my choices.	3
174	As a user I want to have an overview of all awards (badges) to see what I can earn.	7
150	As a user I want to see the awards (badges) I have earned when I open the app.	7
151	As a trainer I want to be able to create and administer training plans in a dashboard.	6
167	As a trainer I want to be able to create and administer group training in a dashboard.	6
175	As a user I want to use forums to communicate with other fMOOC users.	10
169	As a user I want to comment on the exercise to share my experience with other fMOOC users.	10

Figure 2. fMOOC user requirements in form of user stories

User requirements related to hardware, i.e. activity trackers, mobile phones and desktop devices, were elicited in interviews and designed in form of a specification list, which was used to select the suitable software for the fMOOC. Example of requirements at the level of hardware related to user engagement with wearable technologies include:

- Wearing comfort: Senior users require the overall comfort of a wrist-worn wearable including an easy and familiar way of fastening the device around the wrist, a flexible band easy to adjust to different wrist sizes.

- Design aesthetics: Senior users want wearable activity trackers to be inconspicuous and not noticeable by others. The preference for simple and modest design aesthetics is linked to the fear of being stigmatised.
- Technical robustness: Senior users value wearable devices with a long battery lifetime and a simple syncing process, at best activated by a single button.

User requirements related to other devices such as smartphones, have been derived from research in this area and confirmed with senior users in pre-test. These requirements include a set of well-known aspects such as larger displays, haptic aids such as a pen, visual aids such as backlight, memory aids such as unified menus [11].

3.3. Instructional design

The instructional design of the fMOOC combines the elements of the Massive Online Learning Course (MOOC) with elements of gamification and principles of seamless learning to create an engaging flow of learning experiences across contexts (online, offline), blending learning with everyday life. MOOCs as learning formats are massive and open per definition, i.e. they are open to everyone and possibly attract large number of learners. In practice however, only a small cohort of highly engaged learners is committed. A typical MOOC, either cMOOC (based around interactions with learners) or xMOOC (based around interactions with content), would be an online course with a specific goal, digital content, learning activities and schedule. Beyond this, MOOCs also aim at providing personalised digital learning experience, which includes options for learners to engage at their own pace and according to their preferences and goals [23]. Personalisation in MOOCs occurs to some extend naturally as distributed learners interact with the content and with each other at their own pace and through collective intelligence enabled by the interaction of the mass of learners forming social and informational networks [23]. Personalization in MOOCs may be also supported by learning analytics, e.g. monitoring login data and adaptive algorithms, which additionally enhance the user engagement.

Gamification is another method to enhance user engagement in MOOCs and mobile Health [17]. Gamified MOOCs make use of game elements such as points, levels, badges and leader boards to reduce learner drop out and draw attention of learners on crucial learning activities [28]. Since the fMOOC is dedicated to enhancing physical fitness as a healthy living habit, some typical MOOC elements have been modified to enhance user engagement. For example, the fMOOC includes not only online but also offline activities and makes use not only of desktop but also of wearable and mobile technologies.

The key principles for designing user engagement in the fMOOC at instructional design level include:

- blending online and physical learning experience in hybrid learning environments composed of wearable, mobile and desktop technologies to enable learning in extended PLEs,
- designing digital content appropriate to the fitness level of individual users and learner interactions related to fMOOC activities, such as training plans, video content and training materials,

- integrating gamification elements such as badges and battles with activity tracking data to enhance an enjoyable, embodied and motivating learning experience in a community of learners.

Figure 3 visualises the instructional design model of the fMOOC with the three aspects described above, i.e. (a) blended learning experience, (b) digital content and learner interactions focused on physical activity, and (c) gamification elements.

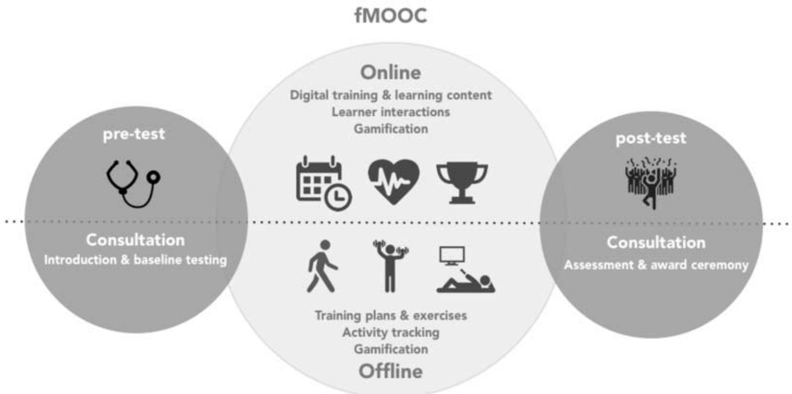

Figure 3: fMOOC instructional design

The participant in the fMOOC first takes part in a group introduction to the fMOOC combined with the demonstration of the fMOOC platform and the wearable activity tracker, followed by a medical consultation with a baseline testing of the overall physical fitness. Based on the results of this consultation, a personalised training plan with a combination of strength and endurance training and integrated rest periods is composed for each individual learner. One cycle of the fMOOC lasts for 4 weeks and is repeated for another cohort of senior learners. Learners learn and interact online and at the same time perform physical exercises such as strength training, walking and jogging in a physical context.

Gamification in fMOOC as a method of persuasive design focuses on two elements - badges and battles - to enhance user engagement. Badges are used both as triggers and as awards. As triggers badges are used to set goals and aim at calling learners to action, thus enhancing motivation [19]. Badges as awards are used to mark progress and recognise achievements. Badges are awarded for (a) specific physical activities, e.g. completing a perfect training plan with rest periods, (b) progress in steps made per day, which are captured with fitness trackers, (c) interactions with other senior users in the fMOOC, e.g. rating and commenting on posts. Battles are used as competitive gamification elements with the aim of enhancing motivation to improve physical fitness. To reduce the risk of negative emotions of those losing the competition, the battles are designed for groups and not individuals and the focus is placed on positive representations of physical activity data within the group. To enhance motivation, battles are designed to make user progress identifiable by the in-group but anonymous to the out-group [24].

3.4. Architecture design

In this section we give a short overview of how the fMOOC architecture is designed to enhance user engagement. The fMOOC architecture combines wearable, mobile and learning technologies to capture and share fitness data and content such as training plans and exercise videos within the community of senior learners. The architecture integrates mobile, wearable and desktop technologies to enhance a seamless integration of the fMOOC activities into everyday life. Figure 4 shows the architecture designed to implement the fMOOC project. Senior learners access fMOOC via the "fMOOC mobile App" using indifferently a laptop, a tablet or a mobile phone. The functionalities of the software are realized by a number of services. The content service connects to the Learning Management System (LMS) Moodle where the content such as training plans and exercise videos, is stored. The communication service also uses the communication facilities of LMS Moodle. The tracking service connects with the fitness tracking data service of the wearable devices to retrieve appropriate data such as the number of steps as measured by an activity tracker. The learning analytics module displays an overview of their fitness data to learners including the exercises of the training plans they have completed. This module makes use of the interactions data stored by Moodle and by the wearable devices. The fMOOC software includes a gamification service to incorporate rewards and playful elements in the course including badges and battles with the aim of enhance user engagement.

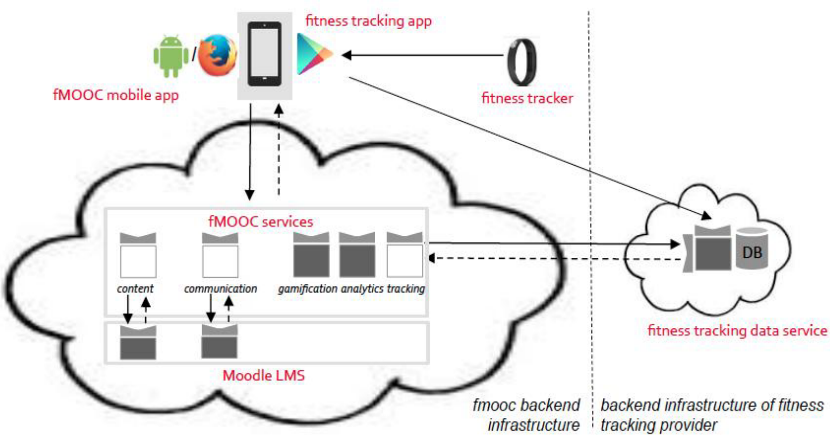

Figure 4. fMOOC architecture design

The architecture design of the fMOOC software system had to face two main challenges. The first challenge results from the fact that most of the activity trackers currently available on the market are not straightforward in supporting APIs thus impeding access to fitness data by other services that can leverage this data for specific groups of users. The available trackers come as a self-contained closed infrastructures, consisting of the actual tracking device, a backend service for storing the tracking data and usually a native mobile application that is responsible for registering users, for synchronising the data stored on the tracking device with the backend service and for providing statistical evaluations on the personal tracking data. For application in the fMOOC system it appeared necessary to obtain an individual view of the tracking data, independently of the existing evaluations of the tracking provider, and to integrate evaluations of tracking data in the fMOOC user interface. Therefore it was necessary to foresee a backend-side integration of the data service of the tracking provider for accessing raw tracking data and for making them available for evaluation in the fMOOC. The second challenge we faced was the integration of the LMS Moodle. The requirements analysis showed that although Moodle enabled some key fMOOC functionalities, it restrained the intuitive usage and senior-friendly user interface. Therefore it was decided to develop a mobile fMOOC GUI independently of Moodle and to integrate Moodle as a backend service, mainly for content management and communication of fMOOC participants.

3.5. Interface design

The fMOOC senior user interface has been designed to be accessible for older users (aged 65+) making use of the key usability principles from multidisciplinary usability research, e.g. psychology, computer science, economic studies, engineering [29]. Beyond accessibility, the fMOOC interface design aims at adding value and increasing the aesthetic appeal of fMOOC to enhance user engagement. As senior users experience a number of sensorial, physical and cognitive changes such as (a) visual changes, e.g. decrease in colour perception and contrast sensitivity, (b) acoustic changes, e.g. difficulties in hearing with distracting background noises, (c) tactile changes, e.g. decreasing fine motor skills and sense of touch, (d) information processing changes, e.g. more time for information processing is needed, difficulties in localizing objects and to remembering non-verbal elements, poorer memory for spatial tasks [29], the fMOOC interface design focuses on the following elements to enhance user engagement in view of the age-related changes as well as further generational issues:

- Text characteristics, e.g. larger fonts and high-contrast elements
- Navigation characteristics, e.g. uniform navigation menus, few navigation layers (reduction of complexity),
- Language characteristics, e.g. clear labels in German language avoiding English words such as “log-in”
- Task characteristics, e.g. clear structure and instructions making every step easily recognisable,
- Feedback characteristics, e.g. easily recognisable feedbacks of success or failure of every user action.

Figure 5 provides an example of user interface design optimised for mobile devices.

4. Conclusions

Healthy ageing is a significant issue which concerns all societies. As emerging technologies such as wearable activity trackers provide new opportunities for promoting health, there is a desperate need to develop innovative solutions harnessing new mechanisms for tracking physical activity and capturing personal health information that can assist in healthy ageing. This paper presented a multi-layer approach for designing user engagement for Wearable-technology Enhanced Learning (WELL) for healthy ageing. As senior users experience a number of age-related changes in terms of physical fitness, cognitive, sensory and tactile abilities, designing for user engagement within wearable-technology enhanced learning is an important research challenge. A number of the aspects addressed in this paper has been tested with senior users as part of the iterative, agile development of the fMOOC. These incremental tests inform the subsequent development of the fMOOC software. The fMOOC prototype and a the user study are planned for summer 2015. The empirical results from this research will be used to provide design guidelines for user engagement in wearable-technology enhanced learning for healthy ageing in order to leverage technology benefits for senior users. This will include issues presented in this paper as well as further issues, e.g. related to data security. The results of the user study will be used as proof of concept for the fMOOC solution.

Figure 5. fMOOC interface design

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Smart Ambient Learning with Physical Artifacts Using Wearable Technologies

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Abstract. Wearable technologies have been developing a momentum recently. However, integrated concepts for teaching and learning with wearable technologies are still not existing in the moment. In this paper, we report about a multi-contextual framework for such an integrated concept. It consists of a number of real-world use-cases coming from a third-party funded project, an entrepreneurial teaching course from a technical university and an open source software development strategy. Conceptual as well as technical issues and first experiences draw an optimistic picture while we outline further needs in research and development.

Keywords. mobile learning, wearables, informal learning

1. Introduction

With the ever-increasing pace of businesses nowadays, also the characteristics of life-long learning underwent a steady change. As an example, the construction sector has to deal with new tools and material on a nearly daily basis, while the budget for training of staff is ever decreasing. Commonly, moving the learning situations to the workplace is considered as solution. Together with the shift to informal workplace learning situations [1], new solutions have to be found for conveying learning material to learners. Our approach presented in this work as technical feasibility study is to allow digital content to be linked to working tools or material. Therefore we discuss three scenarios for wearables usage in informal learning scenarios that are motivated from use cases in a third-party funded project. To evaluate the feasibility of our approach, we implemented a Web-based framework for connecting digital content to physical artifacts in an entrepreneurial teaching course. Our system consists of a backend in the cloud and frontend components for desktop, mobile and wearable devices. As a concrete evaluation scenario, we chose to virtually enrich items in an exhibition. The initial findings and considerations about the technical setup are presented in this paper. To allow for building upon our results, the development work is available under a permissive open source license on our GitHub page[1]. We see a huge potential

[1] https://github.com/learning-layers/CaptusBackend

in extending our prototypes to also address challenges such as personalized and localized digital content to take into account prior knowledge, experience, context of use and performance levels.

The paper is organized as follows. First, we give an overview of our terminology and list underlying technological considerations. Then, the concept of our smart ambient learning system is presented, before the concrete implementation is shown. In the end, we discuss our challenges and give an outlook of possible future work in this area.

2. Background

Before delving into the details of our informal learning scenario, the terminology used in the rest of the paper is laid out. Then, technologies for linking digital devices to physical artifacts are highlighted.

The goal of our system is to attach digital content to physical artifacts. Therefore, digital devices are needed for the users to interact with the digital material provided. To offer a wide variety of interaction possibilities, we chose to support various device types and form factors. Here, we define the device class terminology that we use throughout the paper; in the brackets we list concrete instances of these device types that we used during development and test phases.

- As *stationary devices*, we refer to desktop PCs and laptops (Windows and MacBook).
- As *ambient devices*, we refer to public displays, i.e. fixed large-screen monitors that augment a users mobile screen space (a state-of-the-art 50 inch flat TV connected to a Google Chromecast).
- As *mobile devices*, we refer to smartphones and tablets (Nexus 5 and Nexus 7).
- As *wearable devices*, we refer to smart glasses and smart watches (Google Glass and LG G Watch).

Apart from these concrete instances of devices, we are confident that our findings and prototypes can be transferred easily to other brands and models, since we are using Web technologies as the underlying platform. Besides Web browsers being installed on every device, various cross-platform environments like PhoneGap or Sequoia Touch exist that enable developers to transform their applications from HTML5 into native app packages for Android or iOS. This may be especially important when accessing special hardware capabilities such as NFC readers for discovering present physical artifacts. Other approaches for establishing this link are presented below.

2.1. Technologies for Discovery

Making smartphones and wearables aware of the physical presence of artifacts is a crucial requirement for our system to be able to present additional information about these items to the learners. To identify physical objects, an identifier of at least the object's type has to be available on the digital device that the user

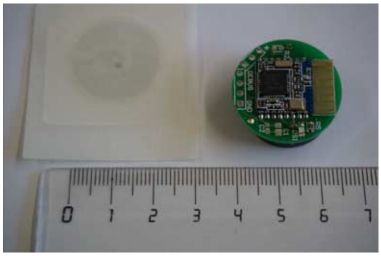

Figure 1. Size Comparison of Near Field Communication (left) and Bluetooth Low Energy Chips (right)

is using; e.g. a *Unique ID (UUID)* that the mobile device can look up to get more details. In the following, we therefore discuss technologies that are useful for establishing a link between a mobile device and a physical information for transferring a limited amount of information.

QR Codes encode certain chunks of information visually, similar to barcodes that are today found on almost every product in supermarkets. QR codes consist of up to hundreds of squares whose arrangement is able to include information as large as around 4000 alphanumerical characters. Over the last years, QR codes have gained huge momentum in street and magazine advertisements where usually the advertised product's website is encoded in a QR code. Mobile apps capable of decoding QR codes are available for free on most mobile operating systems. The main advantage of QR codes is their cheap reproducibility and customizability by simply generating codes on a website and then printing them out on any printer. It is also the most interoperable technology out of the presented ones, as except of a built-in camera, no additional hardware is necessary on mobile devices.

Near Field Communication (NFC) is a contact-free technology for transferring small chunks of information. The principle is known from public transportation ticketing systems and credit cards; the microchip that is usually embedded in the cards has to be held to the reader for a short time so that the data on the NFC chip can be read out. NFC typically works over a range of a few millimeters; it has an active and a passive mode. The active mode allows two NFC devices to actively exchange information over the wireless link; the speed is usually as low as around 100-400 kilobits per second. In the passive mode, the accessing device is sending out wireless waves. Via induction, the field on the sending circuit is activated and the previously saved information is transferred from the NFC chip to the device. These NFC tags are available in different form factors such as the already mentioned credit cards, or simple stickers as in Figure 1 on the left. The NFC technology is available on state-of-the-art Android smartphones and many tablets. Though NFC is recently also available on the iOS platform, Apple limits the hardware's usage to mobile payment.

Bluetooth Low Energy (BLE) is a sub-specification of the recent version of the Bluetooth standard stack for resource-efficient data transfer that is similar to NFC. The circuit for a BLE chip fits on a thumbnail and can be powered by a coin battery for around 1-2 years. To advertise its presence, it periodically broadcasts messages with a configurable signal strength. After calibration, i.e. measuring the

Table 1. Applicability of Physical Object Discovery Techniques with Commodity Hardware

Device	QR Codes	Near Field Communication	Bluetooth Low Energy
PC/Laptop	webcam	–	✓
Public display	–	–	possibly
Smartphone	✓	✓	✓
Tablet	✓	✓	✓
Smart watch	–	–	✓
Smart glass	✓	–	✓

signal strength in 1 m distance, a mobile device may measure its distance to the BLE chip; typically it can reach from a few centimeters to around 70 meters. The iBeacon specification by Apple defines the broadcasted data to be a UUID as well as a major and a minor ID. The UUID is typically the identifier of a specific deployment; the minor and major identifiers mark iBeacons within the UUID. E.g., a retail chain may define a UUID for all its stores, a major ID for a specific store and a minor for a particular iBeacon within the store. While iBeacons are natively accessible through the iOS development framework, libraries with similar functionality are available for Android. Figure 1 (on the right) shows a typical iBeacon.

In this section we discussed different technologies for the discovery of physical artifacts from a mobile device. We defined that artifacts need a unique identifier to be digitally representable. Table 1 shows an overview of the presented approaches and their applicability for the device types presented in Section 2.

3. Scenarios for Learning with Physical Artifacts

In this section, we give examples of real-life scenarios for learning with physical artifacts. They originate from the third-party funded project *Learning Layers*[2] that is dealing with informal learning at the workplace for the construction and healthcare sectors. The scenarios aim to enable different types of digital devices to digitally enhance physical artifacts like tools with additional information. Besides, the objects should be able to be virtually discussed by users.

At **construction sites**, workers have to deal not only with a large variety of building materials, but also with a huge quantity of different tools. As an additional burden for fast adaption of construction techniques, these materials and tools are rapidly changing. Thus in this scenario, workers carry around a mobile device in their worker belt and wear smart watches on their wrists and possibly even a smart helmet[3]. At the start of the day, the workers open a digital toolbox app for getting a list of the day's tasks. The app presents a list of tools like drills and screws to collect. For every tool, annotated videos are available as manuals that can be played in the smart helmet. Additionally, new videos may be recorded and uploaded to a repository for co-workers to be discussed. Finally,

[2] see http://learning-layers.eu
[3] E.g. the one available at http://hardware.daqri.com/smarthelmet/

Figure 2. The Exhibition Scenario

the wearable apps may track the current context to nudge construction workers in case there are subtle optimizations in their work progress.

In the **healthcare** scenario, staff in a hospital carry around tablets and wear smart glasses. When entering a patient's room, healthcare data is automatically loaded on the tablet. Important health data may be displayed on the smart glass during operations as an augmented reality overlay. Finally, alerts on a patient's status may be automatically received on the smart glass at any time, just like pagers notify doctors about certain events (although the authors are aware of ongoing discussions, we neglect ethical and privacy issues here).

The **exhibition concept** can be seen in Figure 2. In the scenario, visitors enter a museum space and then use their mobile and wearable devices for interacting with the exhibition items. Besides the exhibition items on display, more digital material is available in a Web-based backend. Notifications on the wearables guide the visitors to material that can be accessed with the help of mobile devices. Such digital information include a textual description, PDF documents, and multimedia such as audio tracks and videos. Users may discuss the exhibits by adding comments to the digital version of the items and even commenting remarks by previous visitors for enabling a discussion. Besides simply viewing the items, visitors are able to bookmark physical artifacts in a personal library within the system. To take home the impressions and collections after visiting the museum, users may email their library to an email address after the visit, with links to the existing discussion threads for further comments. A public display may temporarily be used to see the content at a larger screen; the material may also be printed out by a stationary printer in the museum. Both versions include Web links to the system so that the discussion may be even continued later on.

3.1. User Concept

User engagement in terms of discussions, sharing and later retrieval of the collected information is an essential part of our system as discussed in the previous section. To keep track of exhibition visitors in the discussions and to maintain the library of bookmarked exhibits, a user management is necessary which includes unique identifiers for users. For lowering the entry barrier, exhibition visitors should be able to use their own accustomed devices and accounts for interacting with the exhibits. The user authentication mechanism in our system is therefore based on the *OpenID Connect (OIDC)* single sign-on standard that is widely supported by big players such as Google and Microsoft. With OIDC, visitors use their third-party accounts to access the exhibition.

3.2. Digital Exhibition

For linking physical artifacts to their digital counterpart, we employ the notion of a digital exhibition repository. This repository contains all the learning material to the exhibits including longer texts, graphics and multimedia elements like audio tracks and videos. While the physical items in the exhibition are possibly fixed in their position, with their arrangement intrinsically suggesting a certain learning path, the digital version may be traversed via links. This may even imply a custom route between the exhibits based on previous knowledge, personal preference or qualification.

3.3. Connection to Physical Artifacts

While moving through the exhibition, users need to be able to get to the digital counterpart of the exhibits through their mobile devices. This step from the physical to the digital world needs to be as easy as possible. Since visitors are able to virtually jump from one item to the other, we also want to support the other way round, from the digital page of an item to the exhibition space. We support this via an interactive room map that displays the position of the items at their approximate real location.

3.4. Reflection After the Visit

To enable reflection, sharing, discussion and extension of the learning materials after the visit, the visited content can be bookmarked during moving around the exhibition both physically and virtually. During the exhibition, this list can be accessed at any time. Additionally, the system compiles the list of bookmarks and allows it to be shared via email. Besides, the material may be compiled as a PDF to be printed on a stationary printer in the exhibition space.

This section presented a number of real-life scenarios for engaging with physical artifacts for learning. In particular, the exhibition scenario was presented in detail as it is the underlying concept for the prototypical implementation of the system that follows in the following.

4. Prototype Implementation

The previous section presented the concept of the ambient learning prototype. In the following, the prototypical implementation is discussed. First, the Web-based backend solution including its WordPress application and the established XMPP network is described. Then, the mobile app as information hub and finally the wearable prototypes for enhancing the experience are shown.

WordPress is an open source blogging software and is one of the most used content management systems on the Web. With its extendable plugin system, WordPress allows to install a wide variety of extensions. For the feature of creating a new information page for an exhibit, we employ standard WordPress pages. The comment functionality allows discussions to take place on every page. This allows to reflect on the material and discuss it with other people accessing the page. To help content creators, we created the WordPress plugin called *Captus* that introduces the notion of exhibition items to the system and displays recent activity on these contents on the front page.

The **Messaging and Presence Protocol (XMPP)** and its several extensions are widely used in instant messaging scenarios to send structured messages between any two or more entities [2]. For connecting exhibition visitors to the physical artifacts and bookmarking items, we leverage concepts of XMPP known from the *Internet of Things (IoT)* [3]. The protocol and its several extensions are widely used in instant messaging scenarios to send structured messages between any two or more entities. In particular, the bookmarking system is implemented as an XMPP contact list; i.e. every time a user connects with a physical object to display its digital information on his mobile device, a virtual friendship is created between the user the and object. The main reason for this architecture is the wide availability of client libraries and servers with the needed functionalities, without having to develop dedicated clients and backend services.

The **mobile app** is the main part of our system that connects to physical objects and all other devices including wearables and public displays. It is operating as an information hub for accessing physical artifacts, the app includes functionality for reading QR codes, touching NFC tags and accessing BLE beacons. Due to missing hardware access in HTML5 for NFC and BLE, we implemented a hybrid solution for Android smartphones based on Android WebViews as a window to the actual WordPress Web content. Another role of the mobile app is the interconnection to wearable devices. The power of this concept is visible if an exhibition visitor approaches an iBeacon. The smart glass then shows a notification about the availability of further learning material.

In our scenario, **wearable apps** are mainly responsible for the smartness of the exhibition by notifying about nearby items. For both wearable types, smart watches and smart glasses, visitors get notified about learning material that is available for nearby exhibition items. We therefore employ Bluetooth Low Energy beacons that are broadcasting a unique identifier every second with limited signal strength. The mobile Android app listens to these requests and then notifies attached wearable devices. In the case of our Google Glass prototype, the wearer may also scan QR codes on exhibition items for opening the digital content on the connected mobile device.

In this chapter, we presented our implementation of the exhibition scenario. In the following, the evaluation of our approach is discussed.

5. Evaluation

The main focus of our research was a technical and developer evaluation of the underlying technologies for creating ambient learning spaces for wearable technologies. We therefore developed parts of the framework in an entrepreneurial teaching course using open source technologies. On the users' end, we only performed an informal user evaluation by showing the prototype at a project meeting with 40 researchers and collecting oral feedback. Though we got positive results for the innovativeness of our solutions, we noticed a lack of awareness for how technologies like localization via Bluetooth Low Energy works. Technically, for connecting physical artifacts we made the best experiences with QR codes and NFC due to their technical maturity. The iBeacons we employed lacked a stable signal strength, we solved this by increasing the broadcast frequency to every 500 ms. A practical issue in our evaluation was the limited battery life of mobile and wearable devices.

6. Conclusion and Future Work

In this paper we presented a system for interacting with physical artifacts using mobile and wearable technologies. As our underlying scenario, we used a museum setting where visitors are equipped with mobile devices such as smartphones and wearable technologies like smart glasses and watches. The concept emphasizes the need of unique identifiers for both users as well as physical objects. During the visit, digital material may be collected and bookmarked in the system. Our main achievement is an integrated framework for developing this new kind of learning applications in an open source software development strategy that was boosted in a project-based learning course at a technical university.

The concept is extendable with gamification elements, e.g. points for collecting items and starting discussions. On the scenario part, sensors for temperature, light or other environmental parameters may be integrated in future for an even more immersive experience. Due to the open source character of our framework, they are easily embeddable into the presented architecture.

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Blended Learning and the Flipped Classroom: The affordances of cloud based, located, and virtual world environments to support student learning

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Abstract. In this paper the author reports on the introduction of the flipped classroom integrating located, online and virtual world learning environments to support the collaborative lived experiences of a group of students and the educator participating in a higher education undergraduate art unit, *Navigating the Visual World.* A qualitative narrative methodology, A/r/tography, incorporating both image making and textual recording is used to explore and identify interwoven aspects of the artist/ researcher/ educator relationship in the creative artistic process of exploring concepts of identity within inquiry based art practice. Selected student examples, including a collaborative group assessment project demonstrate effective student engagement with experiential blended learning within the flipped classroom.

Keywords. Flipped classroom Blended learning, experiential learning , located and online learning, multiuser virtual worlds, art education, visual literacy, collaboration, learning community.

1. Introduction, Background and Context

It is Wednesday morning, and students, singly, in pairs and in groups, arrive for class at the visual art studio. They carry an assortment of equipment, portfolios, rolls of paper, containers overflowing with art materials, laptops, and other ubiquitous technologies. Observation reveals that the majority are young people, second year undergraduate students, intermingled with multiple age students who are returning to study or attending university for the first time. Among the students, there is general agreement that the introduction of asynchronous online study materials accessed before the timetabled class provides them with greater flexibility to engage with the theoretical underpinning of their course work. Audio, visual, video and text based readings linked to preliminary online activities located in discussion spaces and in the virtual Deakin Art Centre in Second Life prepare students to engage with studio based art practice. Amid the general social interaction, the conversation focuses on a recent field trip to Hosier Lane, Melbourne, and other locations, rich in street art (Figure 1b). They comment on art activities they have undertaken in the virtual laneways environment located on Deakin Island in Second Life. (Figure 1a).

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Figure 1a. The laneway on Deakin Island. Second Life[2] .

Figure 1b. Field excursion to Hosier Lane. Melbourne[2].

> ***Figures 1a&1b Journal Entry :*** *But is it art? Is a key theme for students enrolled in the unit Navigating the Visual World. During a field excursion, students explored street art sites found in the alleys and lanes of Melbourne. Using apps uploaded on mobile devices, students navigated from one site to the next in the inner city. On arrival, they accessed a purpose-designed app providing questions, brief and descriptions of various styles and techniques specific to the repertoire of the street artist. They photographed art works and made annotated notes for further discussion and action in the studio and in world.* Journal Entry Art Educator (2012)

These incursions stimulate discussion about immediacy of the visual message, the range of styles, the use of media, and techniques including “pasties, stencils and digital images prevalent in street art. Focused online activities, exploring the posters and artworks of Toulouse Lautrec, Banksy, Kruger, and Holzer make links to off campus excursions and studio art practice. Today, students will collaborate to explore ideas, design and develop visual responses around the theme Identity: A social commentary.

2. The flipped blended learning environment, the Art Educator and the Student

Within the context of contemporary higher education, the flipped classroom incorporating concepts of blended learning represents a technology driven shift from passive face to face lectures to interactive online world-to-the-desktop interfaces [7], virtual worlds and located learning environments, designed to promote independent learning, encourage greater student participation in rich authentic learning tasks and support students individual learning styles. Figure 2 represents the development of a model of blended learning implemented in the undergraduate art unit *Navigating the Visual World.*

Underpinning the model was the concept that immersive blended learning encourages synchronous and asynchronous student participation in collaborative practice and creative problem solving [3,12]. It was further contended that when students engage with co-learners in immersive situated learning, online, in virtual and located environments, the applied knowledge from one setting is transferred to another in increasingly complex learning episodes leading to higher level engagement on the transfer task [9].

[2] Image courtesy J. Grenfell 2014

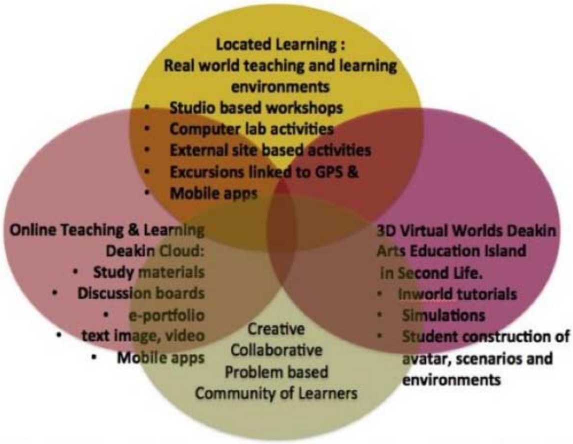

Figure 2. A model of blended learning to be implemented in the flipped classroom[3].

Within a flipped learning environment, the central concept of establishing a collaborative learning community is not new. What was innovative, however, was the formation of an integrated cohort of students engaged in authentic learning to construct knowledge within the disciplines of art and education. This concept is supported by [17] and [22] who believe that participation in common or linked experiences and projects has the potential to establish communities of learners resulting in enhanced student interaction, knowledge exchange, experience sharing and creation. The more participants believe they can learn from a communal sharing of their experiences, processes and project outcomes, the more they are likely to engage and participate as active thinking members of that community.

2.1. The Art Educator

The development of a second year undergraduate art education unit, *Navigating the Visual World* provided the art educator with the opportunity to scaffold a blended learning strategy incorporating a flipped classroom environment. Information accessed from the Deakin student unit evaluation (SETU) database, reporting on study preferences attributed to 21st century learners, their use of ubiquitous technologies and their attitudes to online and interactive blended learning environments were critical elements in determining the structure of the unit. Further student responses revealed that not all participating students conformed to a generational learning preference, particularly when some mature age students displayed more sophisticated skills than those of their younger colleagues.

In developing the unit of study, another concern was whether an educator's lack of advocacy of new technologies and the role they play in active learning, contributed to students' initial perceptions and reluctance to participate in technology based learning communities. Limited expertise in the application of digital technologies as a creative medium and as a learning tool was also identified as a potential concern.

These findings encouraged the art educator, to initiate a transformative process.

[3] Devised by J Grenfell 2013

Students and the educator, who traditionally relied on their own individual creative processes and skills, were afforded the opportunity to access the diversity of expertise exhibited among class members, to value the contributions of colleagues and as a group, to develop a learning environment that embraced a shared culture of continually advancing collective knowledge and skills [11]. This does not mean that each student was required to assimilate the collective knowledge of the community, but that individuals, identified as possessing specialized expertise, were invited to facilitate group participation in specific art activities. This is a departure from a traditional teaching model that emphasizes individual knowledge and the expectation that all students simultaneously acquire the same body of knowledge.

Throughout the project, the art educator engaged in a process of self reflection, articulating her own journey to identify ways in which her role among the group evolved and to record whether the educator's teaching style may influence students' interpretation of issues and their responses exhibited in their art works.

> ***Journal Entry Art Educator****: Having the confidence to "let go" and encourage students to take the lead was the first step in establishing a learning community within the group. The move from a traditional to a more collaborative teaching approach required a clear shared understanding of the art learning focus and needed both the educator and students to have a communication of ideas, diverse but complementary*. Journal Entry Art Educator 2011.

2.2. Profile of the Student Learner

Oblinger & Oblinger [14] describe student learners populating a twenty first century technology rich educational environment as neo millennial and characterize them as experiential, digitally literate, interactive and socially collaborative. Within the undergraduate student cohort enrolled in the art education unit, further investigation revealed another diverse student cohort, each with his or her own unique learning preferences. They are variously identified as traditionalists, baby boomers, gen X, and the net generation [7][8][15][16]. Described as inhabiting a technological "melting pot" [14] these students and their neo-millennial colleagues, pose, for the art educator, a unique problem of how to engage all students in establishing a participatory community of practice. Researchers Willms, Friesen and Milton [23] report that some students favor regular contact with educators, and prefer learning environments that build inter-dependent relationships to create a culture of learning. Independent engagement with online and located learning artifacts enabling students to explore and engage with ideas separately or in small groups is another preferred study option. For the educator, this may require a shift from the 'sage on the stage' to collaborator, working with students support their learning styles in order to actively construct knowledge incorporating immersive real world learning experiences.

3. The *Navigating the Visual World* Project

The focus of the *Navigating the Visual World* project was to investigate the lived experience and multiple art learning perspectives of participants and to profile the 21st century higher education student learner to ascertain whether immersion in a technology rich environment resulted in more effective immersive learning practices. It is contended that well-designed online digital and located learning environments incorporating ubiquitous technologies, online activities, located studio projects, and virtual simulations in the Deakin Art Centre in Second life, enabled second year undergraduate students and the art educator to establish a collaborative learning community. This synergistic collaboration [18] incorporating weekly group discussions enabled students to reflect and comment on their participation and contributed to the ongoing development of a vibrant learning environment.

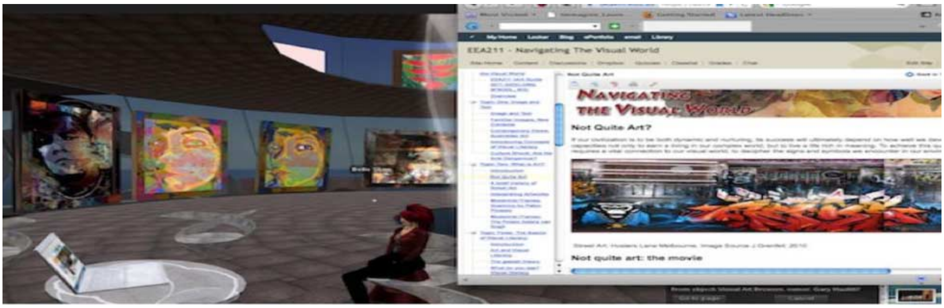

Figure 3. The Learning Environment: Accessing online study materials from within the virtual Art Gallery in Deakin Arts Education Centre in Second Life 2011[4]

3.1. The research process

The adoption of an interpretative narrative research process enabled students to explore the creative processes associated with image making, individually, collaboratively and with the viewing audience. Throughout the project, the research methodology implemented by both the art educator and participating students, A/r/tography, is identified is a form of practice-based research within the arts and education. Drawing upon the professional practices of artists and educators, the process can be described as rhizome like in character [19] an assemblage of objects, ideas, and structures that move and re configure to create new understandings and forms of engagement. Students' visual journal entries, aural recordings and videos, digital artifacts, photographs, art educator observations and documented student led forums, articulated new ideas, and knowledge in the process of recording their engagement and participation in art activities and assessed projects.

3.2. The narrative of visual journals

Visual journals were introduced to enable students to research their own practice and to develop an embodied and relational understanding between self and others [10][19]. Throughout the trimester, the students' visual journals became a platform in which they recorded explored ideas, beliefs and opinions through image and text.

For example, during an introductory computer workshop designed to minimize the 'digital divide' encouraged students with advanced skill levels and capabilities to work collaboratively, to develop creative and technical digital manipulation skills among lesser competent class members [8]. The positive outcomes from this activity are

[4] Image reproduced with permission J.Grenfell. 2011

recorded in the images and accompanying journal entries (Figure 4a and Figure 4b) from two students who worked together on the exercise. Their comments illustrate the diverse range of computer skills identified in the class.

Figure 4a. Exploratory exercise appropriation and digital image manipulation.[5]

Figure 4b. Exploratory exercise appropriation and digital image manipulation.[5]

> ***Figure 4a. Journal Entry****: In this activity I appropriated Da Vinci's "Drawing of a Woman". The original image depicts a serene woman, with the face beautifully rendered but the hair and neck merely suggested with sketched lines in order to keep the face as the focal point. The face almost appears to be coming out of the drawing, as though peering through a veil. I chose to appropriate this image because I admire the woman's beauty and serenity, as well as the skill displayed by the artist. I was trying to show my appreciation of Da Vinci's skill and my desire to learn by paying homage this way. Instead of drawing with conté-crayons, I created my image with photo-shop by selectively cropping an image of myself and then merging it with the original drawing through various filters and careful editing. I ended up with a much warmer hue than the original, but decided to leave it that way because it better suited my personality*. Journal Entry from Y Generation student. (2011)

> ***Figure 4b. Journal Entry:*** *Wow, what a process!! For a Photoshop virgin I think I did all right! There's obviously much room for improvement, which I think, can be seen most in top right- appropriation (where mazzas face is coming through way too much). It was tricky for me to change the colour of my face to the vivid colours that Andy Warhol used, but I think it still has a level of success. Keen to practice more!!* Journal Entry from Baby Boomer student. (2011)

During a class activity, students applied their online research into David Hockney's technique of photomontage and adapted the concept using a drawing medium in their explorations of *Personal Identity:* They recorded personal responses to the concept of self identity embedded in the process of portraiture, linking image and textual responses to accompany their image making.

5 Image J Grenfell 2011

Figure 6. Students explored David Hockney's technique of photomontage and adapted the concept using a drawing medium in their explorations of *Personal Identity.*[6]

***Figure 6 Journal Entry**: Art is important in my life because of it's freedom, art is subjective and does not stereotype it allows you to explore issues that are not commonly spoken about. Having that freedom has allowed me to find something that I enjoy and is for me, it enables me to have fun and explore. I feel that art is not just paint and canvas but is music, ink, drama, film, cooking, anything creative or that shares something about you. Being in a large family and having somewhat of a challenging childhood I love having this freedom to express myself without others involving themselves. It is my voice.* Journal Entry Comment from student D.

Throughout the trimester, students engaged with selected ubiquitous technologies and traditional artistic processes to focus on the theme *Identity: A social commentary*. In researching their artistic practice, students participated in visual journaling to record and explore individual creative artistic processes and to inquire into the role of collaborative learning in image making.

Figure 7a. *Take a Rest* Banksy, Retrieved from Banksy vs Bristol, an exhibition at the Bristol museum, June 2009[7].

Figure 7b. *What could be*? Karen Kupresanin,[8]

***Figure 7b Journal Entry** : I really like Banksy's piece 'taking a break' so when it came to doing my activity on appropriation I used it as a base idea. After thinking of a number of issues I could address in my work I decided on child labour. Due to my studies in primary education the issue of child labour is of importance to me as it prevents the children from receiving an education. The images I used to make my piece were all found using Google images*. K. K. Student Journal entry 2013

[6] Image courtesy J.Grenfell 2012

[7] http://news.bbc.co.uk/local/bristol/hi/people_and_places/arts_and_culture/newsid_8096000/8096891.stm

[8] Reproduced with permission. J.Grenfell. 2013

Connelly & Clandinin [5] contend that humans make meaning of experience by telling and retelling stories about themselves. Students' personal learning journeys [1] and the interpretation of the lived experience [21] encompass art making and engagement with virtual scenarios and online learning. This notion of the lived experience was chosen for its ability to capture the immediacy and subjectivity of experience[20]. The introduction of contextual and personal frames enabled participants to explore how meaning is constructed as they visually interpret personal experience and the world around them[6].

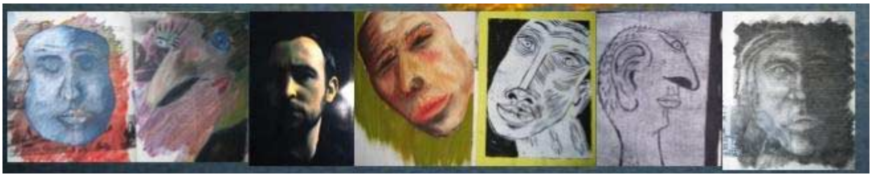

Figure 8. Traditional student exploration of the theme *Identity* using traditional art techniques . (Image courtesy J Grenfell 2011)

Figure 8 Journal Entry *:My artistic decision-making included the construction of a visual dialogue, incorporating image, text and video and recorded responses that I published in the online discussion room and in class in my visual diary.* Student online discussion entry 2011.

Throughout the trimester, the collaborative role of the art educator was to encourage active participatory dialogue between individuals and within the group (Barnacle 2001). All participants including the art educator engaged in regular journaling activities that included reflection and interpretation of individual and collective artistic experience. The process captured a *"phenomenon of life in linguistic description that is both holistic and analytical " [21].* Students documented their creative exploration of ideas, experimented with media including traditional mark making techniques, and the digital manipulation of images. While some students' visual dairies used a more traditional format (Figure 6), other students developed online repositories including websites and blogs (Figure 7).

Figure 9. Extract from Journaling Blog 2012[9].

Figure 9. Journal Entry*: These series of images are part of my visual art practice and focus on a visit to the Northern Territory. As an artist I continually look for new*

[9] Image courtesy J.Grenfell 2012

opportunities or experiences to stimulate my senses/emotions to sketch/paint. The thumbnail sketches are my process of working through how to depict a certain subject and create a clearer image in my mind with which to work with. I used a wide range of materials-ink, ink pen, coloured pencils, acrylic paint, canvas and tin sheets as well as documenting my artistic journey in a diary on video and digital stills. Here, Identity relates to the land and to the relationships that individuals including myself, and different cultural groups have to it. Extract from student blog 2012.[10]

3.3. Art and Virtual environments

Figure 9. Student Virtual Art Exhibition. Identity in Art.[11]

Devised as an assessment task, students participated in a collaborative project to design, build and curate an exhibition of their artworks in the Deakin virtual art gallery in *Second Life.*

At the beginning of the project, participating students chose *Identity* as the theme for the art exhibition. The concept that the artist is a cultural agent who individually and collectively creates visually aesthetic objects for public viewing, underpinned this strand of the project. Students began the creative processes of researching and exploring ideas, experimenting with digital media and techniques to create a collection of artworks. The project encouraged frank discussion of issues relating to gender, class and identity, and how these issues impact on individual lives and personal experience. Students selected artworks and critically examined the definition of art within historical, social and cultural frameworks. They debated the use of irony and parody as strategies for critical social commentary and the appropriation of artworks to fuse fine art traditions and popular culture imagery. Many of their own artworks reflected these discussions. They also considered the practical roles of artists, gallery directors, and curators in the creation and presentation of the artwork within a wider real and virtual community. They debated whether aesthetic contexts are socially constructed through collaborative interactions and conversations about the art works.

Interviews with staff from a regional gallery in Victoria, Australia provided students with valuable insights into curating an art exhibition, including spatial design concepts, relevant to the construction of the virtual exhibition space in *Second Life.*

Building on the concept of a community of practice, students with more highly developed technological skills worked in partnership with less technologically competent colleagues to build an exhibition space to display facsimiles of artworks completed in the art studio. Throughout this process students recorded their experiences, individually in visual journals and collectively using the online discussion

[10] http://wayneelliottartist.blogspot.com.au/2012/07/video-berry-springs-northern-territory.html

[11] Image courtesy J.Grenfell 2012

blog. Throughout the project, it was evident that peer group encouragement was an important factor in retaining student interest and engagement:

> ***Journal Entry Art Educator****: One of the most rewarding outcomes was the willingness of students to support each other, both verbally and through shared knowledge to acquire new technical skills. Individual success in achieving a positive outcome from what may initially have been a frustrating process was met with great enthusiasm withint the group.* (Journal Entry by Art Educator).

This observation is supported by Salmons' [18] concept of the learning community, in which participants, joined by mutual interest, exchange existing knowledge and work collaboratively on shared problem solving activities. Within the virtual environment, increased proficiency in using in-built communication tools, uploading objects including image textures into personal inventories, experimenting with building and 'rezzing' objects in the 'sandpit' further enhanced students growing confidence in navigating and working in a virtual environment. Many students carried out these virtual world tasks away from formal class times. For some, the virtual Deakin Art Centre became a regular meeting place, where their alter ego avatars congregated before teleporting to other *Second Life* sites, returning to report their experiences to fellow classmates and the art educator.

During timetabled classes students held regular meetings to facilitate group decision-making and information exchange. Later, asynchronous in-world meetings became more frequent as students continued to work outside timetabled classes to upload artworks to personal inventories, to collaboratively design and construct the exhibition space and curate the virtual exhibition. Students continued to work in the studio and to upload images and comments onto the online discussion site in *Cloud Deakin*. Their reflective journals recorded individual experiences relating to their art making and engagement in the project.

Observation by the art education revealed that student participation was underpinned by two of the most powerful developments to impact on their art experience, the use of blended learning strategies for art making and the acceptance of technology enhanced artistic practice. The virtual environment offered its simulation platform as open land for students willing to explore digital expression in tandem with studio based art activities, blurring the edges between reality and fantasy to create and reflect student artistic imagination.

Figure: 17. Student images of self using digital imaging technologies were exhibited in the student curated virtual art exhibition space in Second Life [12].

[12] Images reproduced with Permission J.Grenfell. 2011

Journal Entry Art Educator: *One outcome of this development was that the divide between, what is traditionally categorised as high and popular art, diminished as art students pushed the boundaries of innovative creative practice. Giresunlu (2010) supports the idea that when digital artworks undergo a transformation from real life to a simulated digital environment, new contextual avenues for their aesthetic re-evaluation occur. The virtual environment became a social space for its residents to generate three dimensional art works using digital graphic media and creation tools available within the virtual platform. Digitally rendered installations were scripted and built to rotate.* Journal Entry Art Educator 2011).

4. Conclusion

Throughout the trimester, the art educator journal observations, recording the level of individual student and group engagement reinforced the view that the progressive development of a strong technology skills base was crucial for successful participation in the blended learning environment of the flipped classroom. This conclusion was reinforced by individual student journal entries, notes from weekly meetings, including virtual world sessions, and online discussions. End of trimester group discussions reported that the establishment of a technology focused blended learning within a flipped classroom environment had resulted in a more effective community of practice, and a high degree of student satisfaction.

Students reported, that overall, they were fully immersed in problem solving activities that enabled them individually and collaboratively to explore, experiment, research, improvise, reflect, discuss, critique and evaluate their digitally manipulated artworks. However, there were a small number of students who indicated that, although they had developed higher levels of technology and digital manipulation skills, they would prefer to continue to make artworks using more traditional media and techniques in a studio environment.

Finally, the intention of creating a community of learners involving students with different generational characteristics, technological capacities and aspirations, was forged through unified, collaborative, participation in a flipped classroom environment. As technology and educational practice continue to bridge the divide between the virtual and the real, the test for educators is to develop meaningful collaborations relevant to the 21^{st} century learner. This development is only confined by the imagination of the educator, and the willingness to transition from conventional teaching methods to a more collaborative, and social model of learning with discernible real-world relevance.

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Another View of the Empire – Camera Control for Heritage Applications

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Abstract. 'Another View of the Empire' focused on the evaluation of user perspectives and control techniques to help define best practice for the design and implementation of interactive heritage applications. A comparison study was undertaken on two popular avatar control techniques from the field of video games to determine the suitability for integration into interactive heritage environments, where the typical user may not be a regular player of 3D action games. This paper outlines the preliminary research, the design and build of a set of research orientated interactive environments, and the resulting user focused exploratory heuristic qualitative analysis – which found that a hybrid control system may provide the optimum experience for a typical heritage audience.

Keywords. HCI, interaction, heritage, visualisation

1. Introduction

Within the field of video games, first-person perspective is a widely used standard for presentation of, and interaction with, 3D virtual environments. This has been largely consistent and unchanged over two decades, from *Doom* to the latest in the *Call of Duty* series, demonstrating its strengths for human-computer interaction.

The concept involves an avatar, the players' presence in the virtual world, allowing the user to view the virtual world through that avatar's eyes, and viewing the scene from a realistic scale relevant to the players' locations and reducing the requirements for sophisticated player animations or implementation of further camera control functions. Meanwhile, many games also have moved away from the traditional linear style of gameplay, towards the idea of letting users pursue goals of their own choosing. Both of these features drive a feeling of realism into the games they are part of, aiding the high quality user experience.

The first-person free-roaming perspective may be adopted into the field of interactive heritage, and has been attempted in a selection of existing applications, but does this positively affect the user experience? Interactive heritage acts in many ways as a form of 'museum' allowing users to interact with artifacts and architecture of previous generations. With alternative goals to that of video games, and a target audience who may be less familiar with first-person perspective computer games, is it really necessary or helpful to rely on this particular control method, however popular and well known it may be?

A high quality user experience is obviously desired by the users of a wide range of applications, each taking part in a unique process of interaction, bringing their personal desires, anticipations and previous experiences with them to aid interpretation. These experiences are largely context dependent: Blythe and Hassenzah [1] state the same activity can be interpreted as highly pleasant in some contexts but possibly unattractive in others, affected by their own social contexts. Thus research into potential differences between successful video game interaction designs and effective designs for interaction with heritage environments is required. This research can help develop a more comprehensive understanding of how heuristic gaming models can be effectively translated to interactive heritage applications.

As a demonstration heritage application, we consider a 3D visualisation of the 'Scottish Avenue', part of the 1938 Empire Exhibition, held in Bellahouston Park in the south side of Glasgow. The data set itself was digitally recreated by a team of professional modelers, from the Digital Design Studio at The Glasgow School of Art, working from a diverse range of archival information such as small-scale drawings, photographs and maps depicting the design and layout of the exhibition itself. This resulted in a reconstruction of all of the major buildings, from entrance gates to the main pavilions and Tait's Tower [2,3]. Most of these buildings were designed only as temporary pavilions and exhibition spaces, and only one – The Palace of Art – remains in place today.

Figure 1. Interactive Map showing the area reconstructed for the original Empire Exhibition project, www.empireexhibition.com

The typical user for a heritage visualisation such as this would be someone with an interest in local history, perhaps an elderly person with some family connection or personal memories of the event – rather than a typical 'gamer'. Thus, we are interested in discovering whether the popular interaction schemes natural to gamers are equally natural to this distinct target audience.

We note that other control and camera schemes are used in games and interactive visualisations – such as third-person 'over shoulder' camera views, 'top down' views, two-dimensional views, and fixed position cinematic camera systems – but for this current work we restrict our comparisons to the use of a free-roaming first person and fixed position camera systems.

2. Research Methods

Two distinct versions of the 'Interactive Scottish Avenue' visualisation were developed, with identical 3D content but with distinct user control mechanisms. The 3D data used was a subset (Figure 2) of the Empire Exhibition data developed previously [3], and which had been optimized for real time applications. Unity3D, a popular game engine, was then used to create the interactive visualisations.

Figure 2. Entrance Gates of the Empire Exhibition, acting as the introductory screen for the application

Although there are issues with relying on user reported qualitative feedback and responses – including a lack of rigor and objectiveness and a bias towards the subjects and researchers personal feelings and opinions – Patton & Cochran [4] outline how this can form a base on which to further build quantitative research. Accordingly, for the pilot study detailed here, a simple qualitative survey was developed to collect feedback from users on the two control mechanisms implemented, these results to be used in informing further research and development work.

2.1. Research Design

Pinelle, Street and Hall [5] describe how the video game industry has often approached evaluation in a very informal manner, directed towards user opinions and enjoyment, more than scientific assessment. With adoption of techniques from the field of human-computer interaction, more formal methods are also used and considered. Some approaches focus on, for example, the continuous monitoring of data that indicates emotional state during game play as a means of supporting a more rigorous assessment of user experience [6]. However, Sánchez, Zea and Gutiérrez [7] believe that there is still a lack of solid evidence regarding the application of standardized research practices to measuring gameplay experience, and note a need to evaluate against a range of aspects, or facets, of game play experience. Detailed understanding of both conceptual and individual factors that describe gameplay are defined by the heuristic-based evaluation approaches regularly employed, but are regarded as limited in terms of the experience of the evaluator [8].

Existing models give insight into potential methods and techniques relevant to define the quality of a user's experience, but these specific terms of quality are still debated. One of the practical approaches to evaluation is to use the standard ideals of play testing in conjunction with different sets of design heuristics to create a board categorical model of the desired gameplay experience, as no single method provides an inclusive theoretical stance. Play testing in general has generally been conducted with a large degree of informalism, leaning on aspects of the user's enjoyment, although Isbister and Schaffer [9] demonstrate how considerations from human-computer interaction can be used to develop a more comprehensive game-play evaluation. Within existing human-computer interaction approaches, Drachen and Gobel [10] describe different categories to define different aspects of the user experience over time. In terms of this research the focus will be on the quality of the user interaction with the virtual heritage environment, taking into account the impact of interaction mechanics and player behaviour.

To define the quality of the user experience, the human-computer interaction definitions of immersion, presence, interactions and relevant studies were chosen to help define relevant evaluation criteria. Immersion is viewed as a critical piece of any virtual enjoyment, describing the ability of people to become so engaged with a virtual experience they lose recognition of the world around them, a desirable outcome of the intended virtual environment. Studies focus on the descriptive rather than the predictive, although Jennett et al. [11] makes clear factors that aid in achieving these levels of immersion, such as a lack of awareness of both time and the real world, whilst experiencing a sense of presence within the interactive environment. In regards to how user's interactions affect the sense of presence, it can be considered a level of experience where the technology and the external physical environment disappear from the user's intrinsic sense of awareness. Riva [12] states that the illusion of presence causes the human cognitive, processing and sensory systems to define 'entities' within the virtual experience as parts of a genuinely perceived environment.

3. Interactive Application Design

Using Unity3D, two interactive Empire Exhibition applications (Figure 2) were developed – identical in content other than the control systems employed. These are detailed below.

3.1. Free-Roam Perspective (FRP)

The concept of the 'free-roaming' perspective is directly related to a common viewing and control method for video games (namely the 'First Person Shooter' genre although it is not confined to this particular style) and can be seen in its infancy as early as 1993 with the release of the iconic title 'Doom'. Rollings, Andrew and Adams [13] define the concept of a first-person free roaming control method as the graphical perspective rendered from the viewpoint of the playable character, controlled by the user and related to normal movement through three dimensional space. Over the course of the past twenty years this system has been highly refined from its basic origins, delivering viewing method which enables a high degree of fine control over position and view within a virtual environment. This particular method was selected for evaluation due to its popularity in terms of deployment and the familiarity of this method to a portion of the intended user group.

Figure 3. Digital Environment used for the Interactive Scottish Avenue

3.2. Fixed-View Perspective (FVP)

A 'fixed-perspective' camera system is exemplified by the system seen in existing software, derived from Google maps street view (https://maps.google.com), utilizing a fixed position navigation system. Within the software, a user can only navigate by iterating through a pre-set selection of different viewing locations. Variations of this system have existed in games for many years [14], and this approach is recognized for providing a more cinematic view of a virtual environment.

In our case, a fixed position camera was designed to provide a control mechanism that would allow for a selective display of heritage architecture, with the application designer able to specify chosen, and curated, viewpoints and positions. Selection of this method to be used as a comparison also comes from personal experience, with the designer implementing this method with success in a previous project, namely the 'Interactive Blacadder Aisle', [15]. Here users can manipulate the camera's location and cycle through multiple pre-defined locations across the environment, providing focused and views of the Empire Exhibition buildings themselves, and their spatial relationships.

4. Research Analysis

A survey was developed, with reference to Witmer's Presence Questionnaire [16]. The questionnaire generated a range of numerical responses, evaluating different aspects of the users cognitive responses, immersion, presence and interactions, demonstrating each aspect on a five point Likert scale, defining preferred user categories as laid out by Morrill et al. [17]. Participants were recruited through snowball sampling, and from this a number of participants fitted Morrill et al.'s pre-defined categories (e.g. 'experienced gamer' or 'non-gamer'), but did not provide a sufficient number of responses to satisfy independent analysis of each different category. Overall only a small number of users would fit into either the 'high' or 'no' experienced categories (of expert gamer and non-gamer), thus user groups were more generally defined and evaluated in terms of two categories defined by existing experience in either interactive heritage applications (direct) or computer games (indirect). 17 respondents completed the survey after playing the fixed-view perspective variant, and 14 completed the survey after playing the free-roaming perspective variant of the visualisation.

4.1. Preliminary Analysis

Overall, user experience evaluated under the concepts of immersion, presence and user interactions, the FVP demonstrated slightly stronger scores overall, showing a slight improvement over FRP. While noting the small sample size of this study, this shows a slight, but not statistically significant, improvement over FRP. Using a two-tailed T-Test to compare the results from users with limited experience of virtual heritage applications ($n = 21$), some differences between FVP ($n=11$) and FRP ($n=10$) become apparent. In FVP, the low experience users felt more able to examine objects from multiple viewpoints ($M=4.4$, $SD=0.67$) in comparison to FRP ($M=2.8$, $SD = 0.92$, $t(16)=2.12$, $p= 0.0004$). The users also reported that the controls were more easy to pick up ($M=4.3$, $SD=0.81$) in comparison to FRP ($M=3.1$, $SD=0.99$, $t(17)=2.11$, $p=0.006$), and that the control mechanism was less distracting (FVP: $M=2.36$, $SD=0.81$, FRP: $M=3.3$, $SD=1.06$, $t(17)=2.11$, $p=0.037$). No significant differences were recorded for other questions.

In general, experienced users demonstrated greater satisfaction with the user experience whether using the FRP or FVP variant of the visualisation, with only a few discrepancies in either the cognitive response or immersion categories.

4.2. Qualitative Analysis

To gain an interpretative understanding of the generated data, a deductive approach was undertaken from a hermeneutic perspective to construct an interpretative analysis. One of the key aspects demonstrated by the outcomes and user feedback suggests that the FRP delivered a definite sense of freedom to the user experience. Users also felt it was easier to navigate the terrain to exact locations by being allowed to freely move around, in comparison to cycling through the selection of pre-defined locations. This sense of freedom seemed to improve on the grounds of a naturalistic response, presumably down to the 'realistic' control setting directly related to real world movement, making users feel more comfortable.

Within the sample group, a number of users reported that they found the FRP system very natural to use, while other users reported the opposite. We posit that this is most likely the result of some respondents being familiar and comfortable with the first-person controls commonly used in computer games, with other respondents finding this more challenging to learn than FVP – and this would seem to be supported by the differences noted above.

Overall, the FVP responses indicated greater satisfaction with the control mechanism and virtual heritage experience. This was particularly true with regards to the ability of users to evaluate and examine objects (in this case the architecture) in the scene. As allowing users to gain an appreciation of the architecture of the Empire

Exhibition was one of the motivations for developing the models to begin with, this would seem to indicate that while FVP restricts user freedom, it does bring benefits appropriate to our specific desired outcomes. This control system offers users the ability to pan around the buildings from a selection of positions above the ground, providing the user with aerial views, and allowing access to cinematic views with ease. This system may have been preferred in this specific case because the focus of the modeling work is directed towards the architecture over a large area. This technique may not prove to be so effective for projects involving smaller scale environments, such as interacting with heritage objects inside a single virtual room or building.

5. Conclusions and Further Work

The basic research comparing the two alternative control techniques, suggests some distinct advantages of a 'Fixed-View Perspective' for interactive heritage visualisations. The control techniques were both found to score fairly well for ease of use and ease of adoption across the different user categories, but with a small increase in satisfaction for FVP over FRP.

We note that when designing interactive heritage applications, it may be difficult to define a specific target market, but note a need to appeal to 'non-gamer' audiences. This broad user range, demands considerations are made for every different type of user, demonstrating that a technique such as the 'Free-Roaming Perspective', typified by common keyboard and mouse controls for first-person shooter type games, is not necessarily ideal for non-experienced users.

Key advantages have been demonstrated by the FVP, namely the manipulation of the camera to allow for an improved viewing of the models and assets used to populate a 3D virtual heritage environment. The ability to survey a broad range of buildings and views from an assortment of different designer selected camera positions, designed to highlight different aspects and relationships of these buildings was found to be an improvement over the more realistic FRP. The FRP is based on natural human movement and follows the basic laws of physics, resulting in constricting the user to the ground level, restricting potential view of the environment. Even liberated from the laws of physics, the FRP user might still miss the benefits of having carefully curated sets of viewpoints from which to experience the virtual environment as presented in FVP. As gaining an appreciation of the virtual environment's architecture and spatial context is a core reason for the virtual environment's very existence, this is a major negative aspect of the FRP. However, despite these findings, a contradictory note is observed by the increase in freedom of movement enjoyed by users when using FRP.

5.1. Suggestions for Further Work

There is a need for further research of this nature to further explore alternative control mechanisms, and the suitability for a range of audiences. Adaptation techniques might allow applications to offer a range of methods for user control and interaction, but how users can be effectively and accurately matched with specific control systems is far from certain. However, this much is clear – the default control mechanisms common to a wide range of games – and offered as default by 3D development environments such as Unity – are not necessarily the best for virtual heritage. There is also further work to be done on developing tools to support shared exploration of virtual spaces, for a range of collaborative purposes and tasks, potentially building on existing work already conducted with the Empire Exhibition data set.

A further iteration of the interactive heritage environment detailed above allows users to experience both the guided views of FVP and fuller control of FRP. In this, a user can wander round the exhibition area with free movement and full control, being offered the opportunity to view buildings from a range of fixed viewpoints when entering a 'trigger' area near each building. This is yet to be evaluated, but we feel that this may offer a best-of-both-worlds approach for interactive heritage visualisation.

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EdCCDroid: An Education Pilot Prototype for Introducing Code-Combat using LUA

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Abstract. The current paper present a serious game prototype developed to assist the learning of programming at a university level. The game is called EdCCDroid, and is based on Code-Combat, currently the only game field targeting audience for programming learning compared to other games that would see users touch on the purely logically side of programming without having the user entering any code. Code Combat allows users to use script languages such as javascript, Lua, python etc. as input in order to progress through a small story or compete against other players. The paper reports on a "Learn & Play" game prototype that encourages students to understand the fundamentals of programming, through algorithmic design sceptic tasks, using Robots as Avatars to perform certain tasks within the game world. The paper explores the use of the UNITY 3D libraries to design the game, the real-time interactive platform used and the instructions in Lua format. The goal of the game is to produce an attractive game theme environment as part of the game simulation concept, targeting the development of an easy use Head Up Display (HUD) for writing the equivalent task code in Lua., Feedback is provided in case of errors and a visual output of the game state is being produced with the motion/interaction of the game world-bots. The paper also reports on the usability evaluation results from a pilot study conducted with 14 participants.

Keywords. Teaching, Learning Strategies, Interactive Learning Environments, Head Up Display (H.U.D.), Unity 3D

1. Introduction

Computer games have now been around for over three decades and the term Serious Games (SG) has been attributed to the use of computer games that are thought to have educational value. Game-based learning (GBL) has been applied in a number of different fields such as medicine, languages and software engineering [1]. Furthermore SGs can be very effective as an instructional tool and assist learning by providing an alternative way of presenting instructions and content, and promote student motivation and interest in subject matter resulting in enhanced learning effectiveness [2-7]. Games are a great way for people to learn skills such as problem solving and critical thinking.

Game-based learning offers increased motivation and interest to learners through introducing fun into the learning process. Adding fun into the learning process makes learning not only more enjoyable and compelling, but more effective as well [11]. One

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of the main characteristics of GBL is the fact that the instructional content is presented together with fun elements. A game that is motivating makes learners become personally involved with playing it in an emotional and cognitive way. By engaging in a dual level, learner attention and motivation is increased [12]. Systematic literature reviews [14,15] have indicated that playing computer games confers a range of perceptual, cognitive, behavioural and affective, motivational impacts and outcomes where the most frequently occurring outcomes and impacts were affective and motivational followed by knowledge acquisition/content understanding.

Research shows that that GBL and serious games has been applied in a number of different fields such as medicine, languages and software engineering Hainey, Connolly, Boyle and Stansfield [14]. Furthermore, the skills required for success in games such as thinking, planning, learning, and technical skills are skills valued as very i9mportant by employers [16]. Games are frequently cited as important mechanisms for teaching 21st century skills because they can accommodate a wide variety of learning styles within a complex decision-making context [13], foster collaboration, problem-solving, and procedural thinking [17] which are important 21st century skills. Therefore the use of serious games to teach programming seems ideal since it covers a range of skills that are essential in today's world.

Platforms like Scratch and Alice let children (and adults) create their own games and animations using simplified coding methods. Additionally a number of games have been created to teach programming to young children, such as ToonTalk [18], Kodable [19], Lightbot [9] etc.

Lightbot, developed by D. Yaroslavski in 2013 [9] is an educational single player game designed to teach people [has versions for junior (4-8) and above 9+] logically steps in programming. While the game does not involve the player entering code directly it does provide the player with a similar experience from which the player can go on to learn programming more easily. The objective within Lightbot is to use the icons provided to command the light bot to move to and light up all the blue tiles on the map. The player is given instructions towards the start of the game and a very restricted amount of commands available and number of commands to use in order to grasp the basics of the game.

Similar to Lightbot is the *Code combat* (2013) [10], an educational single and multi-player game designed to teach people to code in a multilevel-disciplinary scenarios. Code Combat allows users to input javascript, Lua, python and many more in order to progress through a small story or compete against other players.

2. Game Design for EdCCDroid

The aim of the Code Compact game is to teach the fundamental elements of programming to university students. The game was created in Unity 3D, as a PC Game, and it explores the use of the Unity 3D libraries to design the game using instructions in Lua format. The goal of player is to produce an attractive game theme environment as part of the game simulation concept, targeting the development of an easy use Head Up Display (HUD) for writing the equivalent task code in Lua., Feedback is provided in case of errors and a visual output of the game state is being produced with the motion/interaction of the game world-bots.

Within the game, Lua serves as the main interaction between the player and the Droid. Through Lua the player can direct both the movement and actions of all characters.

Some characters are static, such as doors and others have free movement (i.e.: Droid). In order to enable the player to control the characters the players/learners use an open source library called NLua. Within NLua the players use KopiLua over KerraLua libraries[2] as it is available to free Unity users. KopiLua is a C# implementation of the Lua virtual machine and thus is ideal to use with Unity and C#.

2.1. Game Head Up Display (H.U.D.) forEdCCDroid

The game makes use of a H.U.D. in order to provide the user with information about the game and to enable him to program the droids within the game. The HUD has a basic box on the screen (Figure 1, segment E) with a text editor area integrated and four buttons for the code to compile. The user initially can use the text box to enter the command (or series of commands using loops/ If statements – depending on the level) and then has a series of options: either to direct compile the code, or to save the command into a command history list (for re-usability), load previous saved command (single line command) or load a set of previous used set of instructions (multiple line script). An integrated Timer (Figure 1- segment D) provides feedback to the user for the timer elapsed for the completion of the current level, while segment area B provides the user with the level goal information. Segment area C includes the set of pre-defined set of functions – categorised for each object available in the current level, while segment area A provides a quick access to the objects on the game.

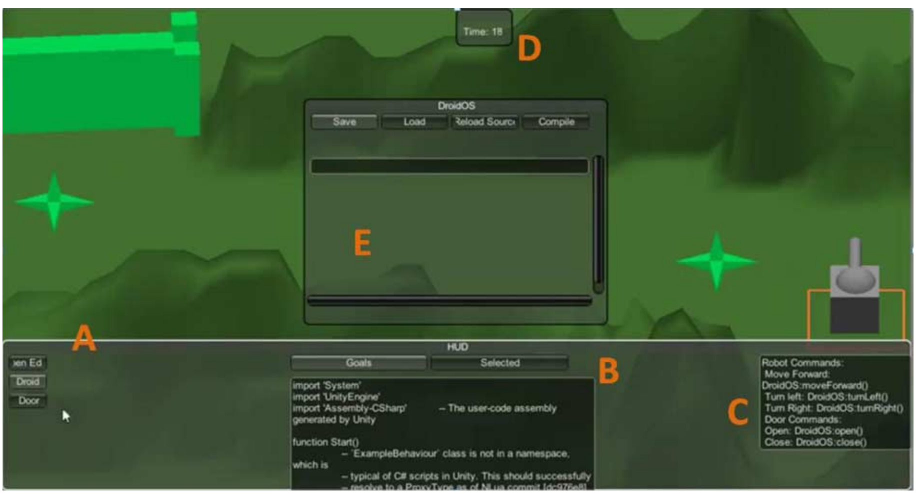

Figure 1. Main game HUD – Five main segments (A-E)

2.2. Integrating Lua programming language for EdCCDroid

To enable the player to have control over game objects, the project required scripts to be edited by the player and then run while the game was running. This required restructuring the way the project started Lua scripts. Whereas previously the scripts

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[2] KopiLua is a pure C# implementation of the Lua Language and KeraLua is a wrapper to the original Lua Language written in C

were stored in the main class and run within the start function provided by Unity. On first restructuring, the compile sequence was moved into its own function and set to start running on a key press after the game had started. The project was once again restructured once a basic Heads Up Display (HUD) was created. This restructuring focused on tying the compiling code to a compile button for the user. This implementation allowed for a dynamic system of code being written during the game runtime and able to be executed.

2.3. User Controlling Object for EdCCDroid

Once the system was put into place to enable runtime code writing, the focus of implementation shifted towards allowing the player an appropriate amount of control over the game object and moving towards multiple object control. Whereas previously the player had access to the entire functionality of the game object, this functionality was stripped in favour of a controller class named "***DroidOS***".

Initially, this class was structured so that the player would reference it in their code. In turn the class would flag boolean values in the game object which would trigger movement code in the update. While this allowed for the players scripting to be more compact it would run all movements simultaneously which was not the intended behaviour for the robots. Furthermore the system would not finish running the player code until a script was compiled. For example if the player run the ***DroidOS:turnRight()*** command the game object would infinitely turn until a new script was compiled.

The solution for these issues was the use of Unity's co-routines. Calls made to the *DroidOS* would, instead of flagging boolean values, add a string to the selected characters command list, then set the character to run. The command list is a list of strings which refer to the names of the characters co-routines for actions. For example the function *DroidOS:moveForward()* adds a string to the robot of "*moveForward*" move forward is a co-routine in the robot.

In order to run a series of commands provided by the player, the characters have a managing function for all the commands in the command list. The run co-routine serves to manage the characters commands so that only one is running at any given moment, while each commands respective co-routine increases the counter which determines which command is currently running and flags a Boolean value as true until it has finished its task.

2.4. Game Commands for EdCCDroid

For the purpose of the game level scenarios, a set of Character commands were implemented for the user:

- *moveForward()* : handles both the movement and animation. Due to the nature of co-routines, the code works by incrementing the location of the robot slowly. Once the robot reaches the end of the movement the robot is no longer flagged as acting and the run co-routine will start the next command.
- *turnRight()/turnLeft()*: handles both the turning of the robot using a rotation angle based on upon a timer. The timer is incremented by the change since the last running event. This causes some minor stuttering while rotating due to the inconsistent nature of the co-routine time step, though the final result is unaffected.

- *open()/close():* Set of commands to handle the door open/close functionality. By using the lerp function over multiple iterations this provides the movement and animation for the door.
- *findTargets()/aimAtTarget : findTarget()* routines designed to locate targets on the map, and add them to the list of located objects in the robot (Level 2&3) while the *aimAtTarget()* differentiate the list of located objects into friendly/enemy targets.

3. Level Implementation for EdCCDroid Game Prototype

There are three planned levels for the current prototype, each one designed to teach a particular concept or feature of programming to the user. The purpose of level one is to teach the user the basic movement commands and introduce the user to the use of ***for loops*** to repeat movements. For this, the terrain structure for the level (maze) is intentionally lengthy to encourage the use of the loops. There are three information points on this level: The first two instruct the user about the use of for loops and how to interact with droids while the last serves to act as the end of the level (Figure 2-left). Once it has been reached the user will be taken back to the main menu where they can view their score and proceed with the game (Figure 2-right). Information point 2-Figure 2 supports an advance learning procedure to shorten the code, rather than repeat loop fragments.

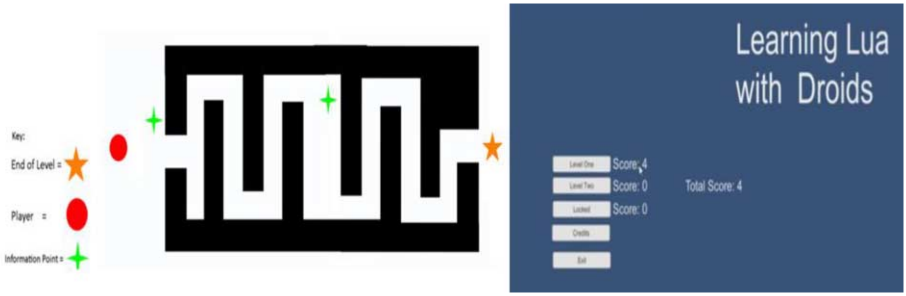

Figure 2: Level 1 EdCCDroid. Two main information points: Learning Loops (left), EdCCDroid Main Menu. Level 2 became active once player one progressed Level 1 (right)

Level two task is to teach the user about ***Arrays*** and building their own ***functions.*** For this purpose the user is provided with an open area and some targets to destroy (Figure 3). The area is however limited to stop the user from being able to exit the map. There is one information point at the start of this level that instructs the user on what to do. Once all the targets have been destroyed the user will be taken to the main menu to see their score.

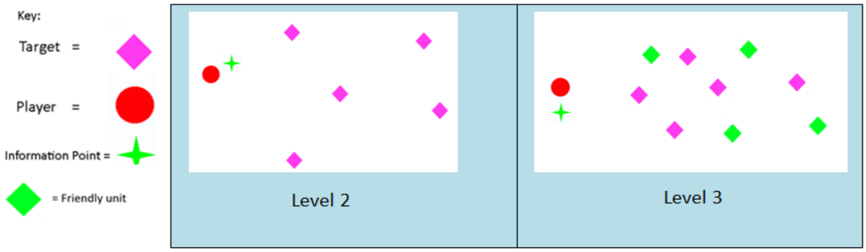

Figure 3: Level 2 & 3 for EdCCDroid

Finally level three aim is to teach the user about the use of ***if statements***. The player will be presented with a similar scenario to the previous level where targets are displayed, however there will be two types of targets to differentiate, one type will be considered "*friendly*" and the other must be destroyed *("enemy")*. The objective for the user is to destroy only the targets that are not coloured green. Destroying a green target will result in the user needing to restart the level. Once all the appropriate targets are destroyed the user will be taken to the main menu to see their score.

4. Evaluation procedure

The pilot evaluation of the EdCCDroid game was carried out with 14 university students (2 multimedia computing, 3 Computer science, 9 computers games development course) with experience in programming but not knowledge of the Lua programming language. Five students were 1st year undergraduates and the rest were 3rd year undergraduate students.
The study took place at the University of Westminster, London premises and each participant was tested individually. Each session lasted for approximately 20 minutes. The participants had to play the game for 15 minutes and then answer a short questionnaire. The questionnaire consisted of 18 questions in total. 17 questions was multiple choice on a Likert scale of one to five (one being the least favourable answer and the five the most favourable answer) and one open ended question. The evaluation focused on usability issues, motivational usability and usefulness of the approach.
All participants used the same apparatus: a Windows 7(64 bit) computer Intel Xeon E5506 with CPU 2.13GHz, 16GB memory and an ATI Radeon HD 5770 Graphics card.

5. Evaluation results on EdCCDroid prototype

5.1. Usability assessment

Six questions were targeted in assessing the general usability of the EdCCDroid game. The results revealed a very positive assessment regarding the usability of the game (see Figure 4). Participants found it easy to use, not very complex and they considered that they did not need to learn many things before starting to use it. Additionally they felt very confident in using the EdCCDroid game and they were willing to use it frequently in order to increase their knowledge of the Lua language.

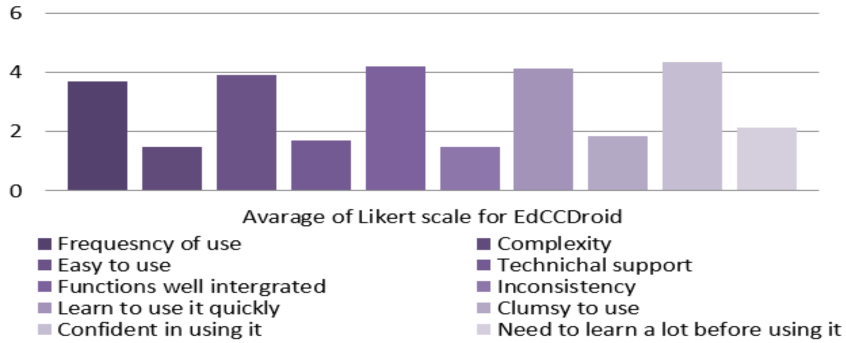

Figure 4. EdCCDroid usability results

5.2. Motivational Usability assessment

Three questions were assessing the motivational usability of the game. The results here revealed some mixed effects (see Figure 5). The participants found the experience very enjoyable (4.2 average) while at the same time they though that it does not incorporate novel characteristics. However, they argued that the game stimulates further inquiry which can be very important for learning.

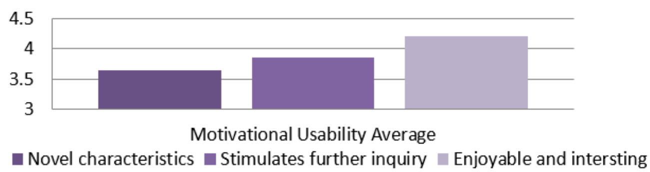

Figure 5. EdCCDroid motivational usability results

5.3. Usefulness and ease of use of EdCCDriod

The last part of the evaluation focused on the usefulness and ease of the EdCCDroid game as a teaching tool. The results here revealed (see Figure 6) that the participants found it very useful (4.6) and ideal (4.1) for teaching programming in general. They also thought again that it was not complicated to use and that it increased their team working skills.

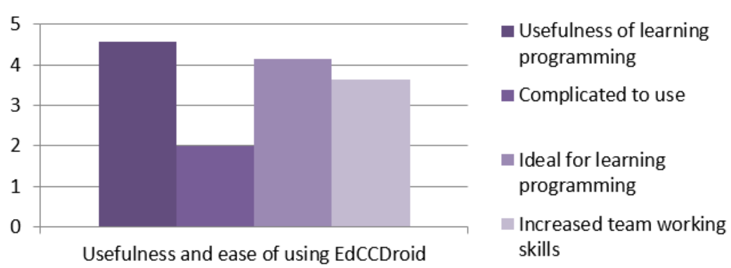

Figure 6. EdCCDroid usefulness in teaching programming

6. Discussion and Conclusions

The usability evaluation of the EdCCDroid prototype revealed some very positive results. Participants in general found it very easy to use, not complicated and they though that it was very suitable to teach programming. However, the current evaluation did not focus on the effectiveness of the learning outcome and this is a shortcoming of the study. The participants had some knowledge of programming so it is safe to assume that their experience made it easier to understand and use the game but at the same time they had not prior knowledge of the Lua scripting language and they thought that the game was a very effective approach which in fact simulated further inquiry. Thus the next steps of the work will be to assess the effectiveness of the learning outcome with the use of pre and post-test questionnaires.

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Collaboration in 3D Virtual Worlds: designing a protocol for case study research

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Abstract. Three-dimensional virtual worlds (3DVW) have been growing fast in number of users, and are used for the most diverse purposes. In collaboration, 3DVW are used with good results due to features such as immersion, interaction capabilities, use of avatar embodiment, and physical space. In the particular cases of avatar embodiment and physical space, these features support nonverbal communication, but its impact on collaboration is not well known. In this work we present the initial steps for creation of a protocol for case study research, aiming to assert itself as a tool to collect data on how nonverbal communication influences collaboration in 3DVW. We define the propositions and units of analysis, and a pilot case to validate them.

Keywords. virtual worlds, collaboration, immersion, interaction, communication, nonverbal, case study, pilot case.

1. Introduction

Three-dimensional virtual worlds (3DVW) have been used for collaboration in several areas such as education, training, and distance learning [1] [2][3][4][5], decision making and planning [6][7][8], project management [7][3], and information systems [9][3]. 3DVW possess features that promote interaction and an immersive environment making them suitable for collaboration [9][3], with the most diverse objectives such as work, social interaction or gaming, are found in World of Warcraft and Second Life [10][11][12][13].

The immersive environment, as well as other features of 3DVW, is also responsible for a sensation felt by users, known as Presence, which occurs when they experience the virtual world without acknowledgment of the mediation of the technology [14]. It is believed that Presence improves collaboration [15], and Romano et al. [16] affirm that collaboration is related to a strong sense of presence shared by collaborators. In the knowledge area that studies the phenomenon of Presence, it is recognized that immersion [17][18][19][20][21][16], nonverbal communication

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[22][23][24][25][26], and interaction [27][28][29] are important for Presence, with the potential for collaboration enhancement.

Nonverbal communication, including clues of presence related to social aspects, such as proximity, orientation of the avatar, focus, eye gaze, eye contact, physical appearance, and the use of avatar itself, strengthen the sense of presence and are important for collaboration [23]. Besides its importance for communication [23][25][26][29], nonverbal communication also improves awareness [23]. In the case of the field of vision, techniques of manipulation and navigation capabilities improve interaction, as well as the immersive environment created by 3DVW, and facilitate cooperative tasks [19]. These facts clearly show a relationship between collaboration and Presence since communication, awareness, interaction and cooperation are directly related to collaboration. Nevertheless, there is a lack of literature on how nonverbal communication cues influence collaboration.

The theoretical framework of the field of Computer Supported Cooperative Work (CSCW) provides a starting point for this work. However, as stated in a recent paper [30], CSCW taxonomies fail to properly address the key features of 3DVW, confounding them with other quite distinct systems. With this work, we want to present a research instrument that enables data collection on how nonverbal communication in 3DVW influences collaboration, and contribute to improve the theoretical framework of CSCW in its ability to classify 3DVW. Generally, we intend to observe a user's behavior and the effect it appears to have on other users' behaviors. With this, we expect to relate some behaviors to specific effects, within a collaboration context, thus achieving data that may contribute to a better understanding of how nonverbal communication cues in 3DVW influence collaboration. The focus on case study research is due to the complex nature of the analysis of users' behaviors. This proposal establishes the first two steps of the case study methodology according to Yin [31], as part of the case study protocol. These steps are Research Design (1) and Preparation for Evidence Collection (2). Further support of this choice is presented in the next section, as well as a summary of Yin's methodology. The third section refers to the design of the research with definition of propositions and units of analysis, and the fourth refers to the preparation for the collection of evidence, including a pilot case to validate propositions and units of analysis. We conclude in the final section with some reflections.

2. Methodology overview

Case study methodology studies phenomena, processes or behaviors in their real environment [32][33][31]. It allows the study of different aspects of the object of study and their relationships [33], namely the "how", the "why", and results [32][34]. This methodology is used to explore processes or behaviors that are new or poorly understood [35], characterized by a non-evident distinction between phenomena and context [31], or situations where it is very difficult, if not impossible, to use other methods besides qualitative ones [36]. Techniques of data analysis for case study may include distribution of data by different categories, creating flow charts or other synoptic, calculation of frequencies, means and variances, and organizing data chronologically [37].

In 3DVW, features such as gestures and emotions are used to produce behaviors reflecting social symbolisms like culture, ethnicity, and religion [6][7][8]. The environment is also used to influence the mood and humor of the users, helping them to socialize [6][7][8]. These behaviors are complex in nature, and are difficult to separate from context, being the spatial environment a good illustration of that fact. These reasons led us to choose the case study methodology for this study.

We follow Yin's [31] perspective on the case study methodology, which is well accepted and used in many case study research efforts. It comprises the following activities:

- Research Design
- Preparation for Evidence Collection
- Evidence Collection
- Evidence Analysis
- Sharing of Results

Research Design begins by defining the issues under study, or in other words, the research questions. After that, comes the definition of propositions, which helps focus the study in the core of the case. The third component of Research Design is the definition of units of analysis, that is, the definition of what concretely will be studied (the phenomenon, behavior, process, etc.). After this, the logical connection of propositions to the data should be made. Finally, the criteria for interpreting the results are defined. After the research planning, the next step is the Preparation for Evidence Collection (or data collection preparation). This implies developing a protocol for the case study – a tool that helps assure reliability in data collection. It includes objectives, framework and relevant literature, procedures for obtaining the data (access, method of collection, calendar), questions to ask, and format of the report with the results. The development of the protocol should be validated with a pilot case. These are the activities presented in this paper. The subsequent activities (evidence collecting, evidence analysis and sharing of results) comprise the future actions and are not the focus of this paper.

3. Research design

In our case, the research questions are concerned with how nonverbal communication affects collaboration in 3DVW. This general concern can be specified as two questions:

RQ1 How does the use of an avatar influences collaboration 3DVW?
RQ2 How does the virtual spatial environment influences collaboration 3DVW?

As for the definition of propositions, in this study they are related to expectations generated by the theory of Presence [15]. Thus, we propose the following set of propositions related to nonverbal communication and the impact it may have on collaboration, based on expectations from previous research on virtual worlds [15]:

P1 The aesthetics of the avatar influence the perception by others of the role of the avatar's user and/or his attitude.
P2 The gestures and sounds that the avatar does influence the perception by others about how the avatar's user wants to collaborate or how he or she wants others to collaborate.
P3 The eye gaze/face direction, direction of movement, and avatar placement provide cues about what the user is paying attention to, or what the user would like to direct others' attention towards.
P4 Interaction of the avatar with specific objects provides cues about which objects are intended to be used by others in the collaboration process.
P5 The arrangement of objects (e.g., their grouping or alignment) provides cues of their purpose for collaboration.
P6 The exchange of visual artifacts (i.e., "objects", "clothes", "tools"), with specific visual features and explicit purposes, helps define the team, contributing to group awareness and perception of collaboration roles.
P7 The virtual spatial environment, including lighting, sound or music, and visual effects, influences the attitudes of collaborators.

We also defined the units of analysis both for avatars and for the virtual spatial environment. Referring to the research questions, the units of analysis for avatars we used were:

- Appearance
- Gestures made
- Sounds emitted
- Eye gaze
- Facial demeanor
- Facial orientation
- Direction of movement
- Body position
- Avatar placement
- Visual artifacts used for interaction

And the units of analysis for the physical space were:

- Animated visual artifacts (animated objects) or artifacts for interaction (i.e. pose balls)
- Non-animated visual artifacts
- Non-visual artifacts (e.g., scripts)
- Visual environment (e.g., what kind of place the action is taking place in)

These units of analysis are the observation targets of the case studies, and their relations with the research questions will be obtained by applying Yin's recommended criteria [31].

4. Preparation for Evidence Collection

4.1. Pilot case

Second life is being used for collaboration in several different tasks, with learning and training as one of the most common [15]. This case was selected for convenience, because we had easy access to it for observation. In the pilot case used, the data was obtained by direct observation. The pilot case is an example of collaboration on an initial training class, where new participants of a group in Second Life learn the basics of building. The group's theme is the Star Trek television series. The group has several activities, among which stands out the construction of objects related to the series, with particular emphasis on the production of spaceships. Thus, it is of great importance for the group's goals to teach newcomers how to build a variety of objects.

4.2. Scenario

For the scheduling of the class, a Second Life group notice was used with date and time (this is a typical text message that is broadcast to all group members). The class was held in an empty space, commonly called "sandbox" in the context of Second Life (regardless of whether it has any actual sand or whether it is an actual box or – most likely – not), large enough to build even space stations. This sandbox space had many participants moving around, positioning themselves close to some of the objects, and often facing them. It was possible to observe beams of light balls coming out from the hands of some of the avatars towards some of those objects. These are Second Life's cues to indicate that an avatar is editing an object, so it was no surprise that the presence of those beams coincided with striking visual changes in the objects to which they were emitted. The class consisted of several avatars, dressing uniforms and bearing titles visible as text hovering above their heads, identifying them as several cadets, two junior officers who constituted the instruction team, and a senior official responsible for the supervision, as explained by one of the instruction team members. Participants unaware of the significance of titles and uniforms could check them in a text file, which alongside others (with rules, schedules, activities, etc.), as well as uniforms, titles, and other objects, are available to group members at a dedicated warehouse. Usually, these resources are informed to newcomers by a host.

4.3. The class observation summary

As soon as all participants gathered around the instruction team, forming roughly a circle, the instructor used the voice channel to present himself, welcoming everyone, and to transmit certain operating rules for the class. Besides rules, the roles of each instruction team member were also transmitted to the group, as well as a summary of the program for the class. The instructor offered to explain while demonstrating, and began to do so. While explaining, an object came up in front of him. A beam of light balls coming out of his hand towards the object pointed out he was editing it, and indeed changing as mentioned by the instructor. Students emitted similar beams towards objects that appeared before each of them. This indicated which object each one was editing, and those objects started to change shape as the instructor's had. After explaining using voice communication how to control the most basic properties such as shape, position, and dimensions, and a few others, the instructor started to talk about the control of color and texture of objects. He mentioned that he would render a chair, and a chair appeared in front of his avatar, after which he urged the group of cadets to make an equal one as an exercise. He also said he would distribute a texture to be used in the chairs, using Instant Messaging (IM) as a means of distributing the resource containing the actual texture. Several objects came up on the ground near each other, as a sort of grouping, before each student. Again, beams of light balls were emitted from the hands of the avatars towards the objects that began to change shape, position, or texture. Further along in the class, the overall position of those groups of objects relative to each other revealed them to be chairs similar to the instructor's. Sometimes, some students issued messages in text chat, or made their avatars start animations/sounds such as waving and whistling. Upon occurrence of those animations or sounds, the instructor and assistant would address the source avatars, communicating by voice. It was observable that sometimes from the hands of the avatars of the instructor team, beams of light balls would come out again towards the objects in front of the students, changing them. After everyone finished the exercise, with varying degrees of success, the class was declared ended by the instructor.

4.4. Evidence collection in the pilot case

The evidences were drawn directly from the description of the above case. Thus, each reference to the use of a feature or behavior was accounted as evidence, relating it to one or more units of analysis, according to the impact of the evidence described in the unit. Not all of the units of analysis have evidences in this case. Table 1 summarizes the evidences of the units of analysis for the avatar, with a brief description of the reference of the case description. Similarly, Table 2 summarizes the evidence of units of analysis for the physical space.

4.5. Evidence analysis in the pilot case

To analyze the collected data, several evidences were related in order to create a chain of evidences to support each of the propositions mentioned above. Table 3 summarizes the propositions and the chains of evidences supporting them. Each proposition has one or more chains of evidences, each beginning with an evidence of a unit of analysis directly related to the proposition, as shown in Table 3. The other elements of the chain may or may not be from the same unit. In some cases, evidences taken directly from the case were added to help clarify the relationship.

The first proposition related the appearance of the avatar, is supported by the fact that all participants' avatars wear uniforms. The meaning of the different uniforms is available either textually or verbally. Referring to gestures and sounds, the second proposition is sustained by the reaction the instruction team had in assisting the students, when some of them used gestures and sounds, sometimes accompanied by messages in chat. The proposition on the direction of movement, eye gaze/head direction or avatar placement is supported by two chains of evidence. The first is related to the movement of other avatars who do not participate in class, but their physical attitudes, gestures, and interaction on objects, reveal their activities. The second chain starts at the reunion of students around the instruction team, which triggered the beginning of the instructor's exposition. The following proposition, related to interaction with objects, is also supported by two chains of evidence. The first is based on the object used by the instructor to reflect the intentions expressed by him, leading students to imitate his actions. The second, it is based on the exercise proposed by the instructor, which urged the students to build a similar chair to the one presented.

Table 1. Evidences of the units of analysis related to the avatar

Units of analysis	Evidences
Appearance	All participants' avatars were dressed with uniforms.
Gestures made	Beams of light balls could be seen coming out of the hands of some of the avatars. A beam of light balls was emitted from the hand of the instructor towards the object of exemplification. Students emitted similar beams towards objects that came up before each of them. During execution of the chair-building exercise, light beams where emitted from the hands of several avatars towards objects that changed shape, position and texture. Beams of light balls would be emitted from the hands of the instruction team towards objects of students, changing them.
Sounds emitted	Some students made calling gestures and/or sounds such as waving and whistling.
Direction of movement	Instructor and assistant walked towards the students.
Avatar placement	The sandbox had several participants moving around, positioning themselves near some of the objects and often facing them. Participants gathered around the instruction team, forming roughly a circle.
Visual artifacts used for interaction	Visible changes of the physical objects near avatars were observed. The instructor's object reflected the changes mentioned by him. Objects near students changed in a similar manner to the instructor's. The instructor rendered a chair. Objects appeared in apparent groupings in front of each student. Students' objects changed shape, position and texture. Light balls were emitted by the hands of the instruction team towards objects of students, changing them. Objects in front of each student assumed a spatial positioning resembling a chair.

Table 2. Evidences of the units of analysis related to the physical space.

Units of analysis	Evidences
Non-animated visual artifacts	The instructor used an object for demonstration. The instructor rendered a chair. Objects appeared in apparent groupings in front of each student. All avatars had text titles visible over their heads.
Non-visual artifacts	The scheduling of the class was provided by a group notice with date and time. Text notes with rules, schedules and activities, are available to group members, as well as uniforms, titles and other objects. The instructor distributed a texture using IM.
Visual environment	The class was held on a large empty space ("sandbox").

TABLE 3. Propositions and evidences/units of analysis related.

Proposition	Evidences	Related Evidences	Additional evidence
The appearance of the avatar influences the perception by others, of the role of the avatar's user and/or his attitude.	All participants had uniforms.	Text files, with rules, schedules and activities, are made available to group members, as well as uniforms, titles and other objects.	The interpretation of titles and uniforms is available in text files. This and other texts (with rules, schedules and activities, etc.), as well as uniforms, titles and other resources, can be obtained in a warehouse. The instructor transmits some rules, including the roles of each of the instruction team member.
The gestures and sounds that the avatar does influences the perception by others about how the user in question wants to collaborate or how he or she wants others to collaborate.	Some students made gestures and/or sounds such as waving and whistling.	Instructor and assistant moved towards the students. The instruction team emitted light balls beams towards objects of students, changing them.	Some students used messages in chat, or made animations and/or sounds, after which the instructor and assistant addressed those students, communicating by voice.
The focus, walk direction, or position of avatar provides clues about what the user is paying attention, or what the user would like the attention be paid to.	The sandbox had several participants moving around, positioning themselves near some of the objects and often turned at them.	Beams of light balls came out of the hands of some of the avatars within the sandbox. Visual changes in the physical objects near avatars were observed.	
	The participants gathered around the instruction team, forming roughly a circle.	The instructor used the voice channel to introduce himself, welcome everyone, and transmit rules.	
Interaction with certain objects by the avatar also provides clues about which ones are intended to be used in the collaboration.	The instructor used an object for demonstration.	A beam of light balls was emitted from the hand of the instructor towards the object of exemplification The object reflected the changes mentioned by the instructor. Students emitted similar beams towards objects that came up before each.	
	The instructor rendered a chair.	Objects near the students changed in a similar manner to the instructor's. During the chair exercise, light beams where emitted from the hands of several avatars towards objects that changed in shape, position and texture.	The instructor mentioned that he would render a chair, and a chair appeared in front of his avatar, after which he urged the cadets for each one to make a similar chair.

The arrangement of objects and how they are grouped reveals clues of its usefulness for collaboration.	Visually grouped objects came up in front of each student.	The objects changed shape, position and texture. Objects in front of each student were assembled in a visual placement resembling chairs. The instruction team emitted light balls beams towards some objects of students, changing them.	
The exchange of artifacts or objects, their features, and their usefulness, helps to define the team, contributing to the group consciousness and correct perception of collaboration, that is, awareness.	The scheduling of the class was provided by a group notice with date and time. They all had titles visible over their heads.	The participants gathered around the instruction team, forming roughly a circle. Text notes with rules, schedules and activities are available to group members, as well as uniforms, titles and other objects.	
	The instructor distributed a texture using IM.	During the execution of the chair exercise, light beams where emitted from the hands of several avatars towards objects that changed in shape, position and texture.	The instructor distributed a texture to be used in the making of the chair.
The environment, including lighting, sound or music, and visuals, influences the attitude of collaborators.	The class was held on a large empty space.	Beams of light balls were seen coming out of the hands of some of the avatars within the empty space. Visual changes in the physical objects near avatars within the space were observed. The participants gathered around the instruction team, forming roughly a circle.	There is a cultural term in Second Life for designating such empty spaces for building: “sandbox”, regardless of having actual sand or whether it is within a box or not.

The next proposition, about the arrangement and grouping of objects, is based on the fact of the objects that students have in groups near them, having their properties changed to form chairs. This fact is so revealing of completion that the instruction team, when addressing some participants to assist them, used some of these groups of objects for assistance of others.

The proposition related to the exchange and use of objects and artifacts is sustained by three chains of evidence. The first is related to the fact that the participants have gathered at the date and time scheduled by a group notice. In the second chain, the titles clarify each participant’s role in the group. And in the third chain the texture’s function confirms the intentions of the instructor. Finally, the proposition concerning the environment is supported by the fact that the class has taken place on a site whose purpose is to render and build objects. This purpose is supported by its visual properties:

being large and empty, perhaps with a few scattered disorganized artifacts resulting from previous building exercises, which for users of Second Life are all cues enabling the identification of the space as a “sandbox”.

5. Conclusion

In this paper we presented the first steps for creation of a protocol for case study research of Presence and Cooperation in virtual worlds, according to Yin’s methodology. The propositions were defined and validated with a pilot case. Thus, these propositions and units of analysis can be used in future research for evidence collection on 3DVW when used for collaboration.

The pilot case was held on Second Life, in a usual scenario, and with a well known and easy to recreate subject: a class to teach how to build objects. After the description of the case itself, we analyzed it by extracting from the description examples of behaviors related to each unit of analysis. Then, chain of evidences were created by relating evidences based on the fact that each time a behavior of a avatar or group of avatars, had as consequence, behaviors on other avatars. These cause/consequence relations where used to support the propositions. It was possible to find at least one chain of evidences for each proposition. This process can be replicated with more case studies to provide multiple sources of chains to support the propositions in order to have enough confidence on them, and only then, share them.

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Advancing Physics Learning Through Traversing a Multi-Modal Experimentation Space

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Abstract. Translating conceptual knowledge into real world experiences presents a significant educational challenge. This position paper presents an approach that supports learners in moving seamlessly between conceptual learning and their application in the real world by bringing physical and virtual experiments into everyday settings. Learners are empowered in conducting these situated experiments in a variety of physical settings by leveraging state of the art mobile, augmented reality, and virtual reality technology. A blend of mobile-based multi-sensory physical experiments, augmented reality and enabling virtual environments can allow learners to bridge their conceptual learning with tangible experiences in a completely novel manner. This approach focuses on the learner by applying self-regulated personalised learning techniques, underpinned by innovative pedagogical approaches and adaptation techniques, to ensure that the needs and preferences of each learner are catered for individually.

Keywords. Physics learning, physics experiments, mobile devices, virtual worlds, augmented reality, self-regulated learning, personalisation

1. Introduction

Competence in science, technology, engineering, and maths (STEM) is an important pillar of today's knowledge economy. However, shortages in STEM expertise and interest in STEM careers can be identified across Europe, in particular in the field of physics and mathematics. In addition, there exists a significant gender imbalance in STEM fields, with women being historically underrepresented. As a result, STEM education – and how to make it more effective and appealing – is still an important goal of the European

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educational system. Ways of making science education and careers more attractive for young people are sought and the use of new tools and innovative pedagogical approaches in teaching STEM is promoted (e.g. [15], [12]). Different successful pedagogical models for STEM fields use teaching methods which promote hands-on, collaborative, visual, and discussion-based activities [10] [6].

In this view different approaches have accepted this challenge and have their way in science education in general and physics education in particular. The strong real-world link is a core feature especially of “context-based science education”, which has a long-standing tradition and is considered to be a highly promising approach in science education [7], [3], [20], [24]. Context-based science education (CBSE) is currently broadly understood as “using concepts and process skills in real-life contexts that are relevant to students from diverse backgrounds” [9]. Making science issues relevant to students and the social group they live in (peers and relatives) counters the widespread perception of physics as being dry, impersonal, and irrelevant. In this view different CBSE classroom settings have been developed and implemented. Although this approach is promising, its effect on conceptual learning and problem solving is contradictory [19] [17].

Therefore beside the motivational aspect of translating conceptual knowledge into real world experiences a very important cognitive aspect has to be considered: It’s well known that competent handling of multiple representations is supposed to be significant for learning and solving problems – especially in science education [1] [2]. Furthermore researchers have found that integrating multiple representations (especially visual ones) could afford a better conceptual learning environment for many students [6] [8] [23].

Considering these motivational and cognitive aspects, the use of smartphones and tablet PCs as experimental tool offer unique opportunities for establishing multiple links to the real world of learners and boosting their conceptual knowledge and problem solving competence. Furthermore, virtual reality environments have similar advantages, as they can offer simulations of real world experiments. We can therefore assume that this technology has positive effects on the learner’s interest in both science and technology, their self-efficacy, and their learning.

This paper presents an innovative approach for physics learning that grounds on two pillars, which are (1) new developments in mobile devices, augmented reality, and virtual environments, and (2) new advancements in TEL research, including adaptive and personalised learning, mobile and ubiquitous learning. The core piece of this approach is the Smart Learning Environment that provides both a multi-modal experimentation space and a learning assistant that personally supports the learner to traverse through the experimentation space. Though this approach has not been implemented and tested yet, it still includes several components from the authors that have already been developed and tested. The goal of this paper is to outline a concept, how these components can be brought together to advance the physics education.

2. Smart Learning Environment

The core part of the conceptual approach is the Smart Learning Environment (see Figure 1) that empowers learners, students, and the general public to learn physics in new ways. This environment consists of two parts, the experimentation space and the smart assistant. The experimentation space is the technical environment that allows learners to engage with physics knowledge and experiments in different modes and on different locations. Mobile devices and their sensors are used to make various kinds of physics experiments in the real world. Augmented reality applications are used to support the understanding of the underlying physics knowledge. The same physics concepts and experiments are accessible in virtual reality settings that put a different perspective on it. Finally, existing paper-based educational material, such as books, sketches, maps or drawings, are made digitally accessible with the help of further augmented reality applications. The learners can move (traverse) between these modalities and experience learning from different perspectives.

Learning support is provided through the smart assistant that tracks the learning activities, gives personalised recommendations in terms of concepts to learn or resources to use, and personalised feedback in terms of performed activities and achieved learning progress. Furthermore, motivation is stimulated by injecting gamification elements in the experimentation space. The smart assistant also connects the modalities of the experimentation space, so that learners get support in each phase depending on their competence state, personal needs, and previous activities perfomred in the other modalities.

A major characteristic of the smart learning environment lies in its flexibility. It can be applied in both formal and informal settings, because it allows for teacher-regulated learning and self-regulated learning including motivational strategies. Learners can learm in educational institutions, at home, or outside in the real word, and alway get repective support. Details on the experimentation space and learning support are provided in the next sections.

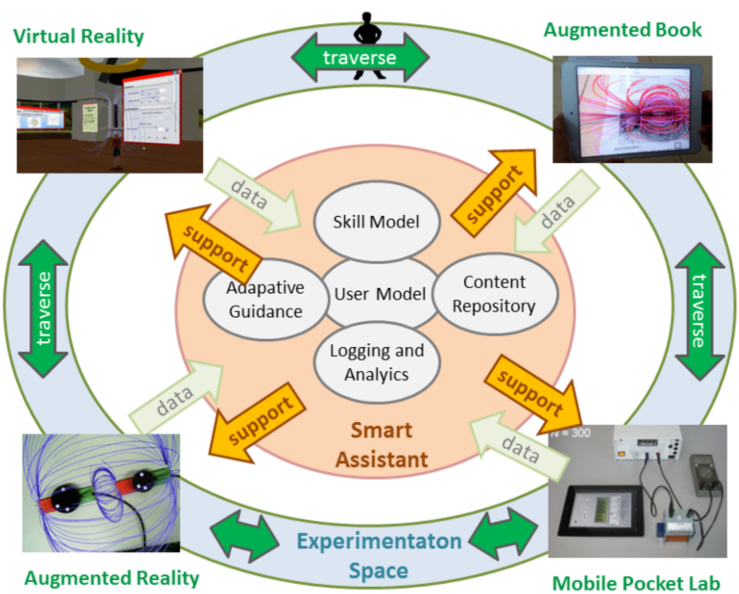

Figure 1. The Smart Learning Environment consisting of the physics experimentation space (outer circle) and the smart assistant (inner circle).

3. Physics Experimentation Space

3.1. Learning Physics Concepts with Augmented, Interactive Books

The first step in a learning process often starts with learning a theoretical concept. Traditionally printed learning material (e.g. books, graphs, exercise sheets) are used to learn concepts. The augmented book refers to the idea of using augmented reality (AR) to enrich the content of printed learning material, be it through the use of mobile devices, or directly on the paper substrate (e.g. through projecting new content). The technology works by detecting the page in view at any time and overlaying new information either over the image of the paper document (when using a mobile device) or in real life (when using projector/camera based solutions). As an example imagine the case of a learner studying magnetism and its relationship with electric current. The AR software then overlays animated examples of magnets and visualises the magnetic field and its relationship to the electric circuit (see Figure 2). The smart assistant logs this learning activity (the magnetism topic) and recommends to try out a real world experiment or other suggested activities. Once the user completes suggested activities, the book can act as the anchor point for concentrating all the new, personalised information collected by the user.

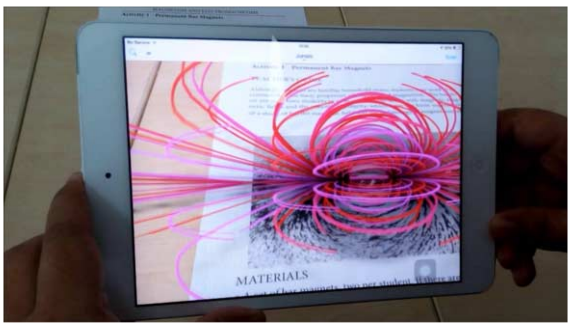

Figure 2. Learning magnetism concepts with an augmented book [Picture taken from a video of VirtuoCity Systems, http://www.virtuocity.my/].

3.2. Real world experience with the Mobile Pocket-Lab: Using Mobile Device as Experimental Tool

With internal sensors of mobile devices students could detect physical data by themselves [16] [18] . For example, to explore the relationships in the framework of magnetic fields the internal magnetic field strength sensor of smartphone/tablet PC is used. In this case, students analyse the relationship between the magnetic flux B of a coil and the electric current I, the number of coil-loops N or the distance to the coil d. Therefore, they first position the mobile device with its magnetic field sensor in front of the coil's longitudinal axis and set up the experiment as presented in Figure 3 (left side). Second, e.g., for studying the B-I-relationship, they start a relevant app (e.g. Tesla Field Meter for iOS or AndroSensor for Android), measure B successively for different I, tabulate the data, and plot the B-I-diagram with the data of the table (see Figure 3, right). In this learning space, students build up basic competences concerning cognitive as well as experimental skills and methodologies in the specific topic. The smart assistant (implemented as app on the mobile device) tracks the activity and relates it to the respective topic on the backend.

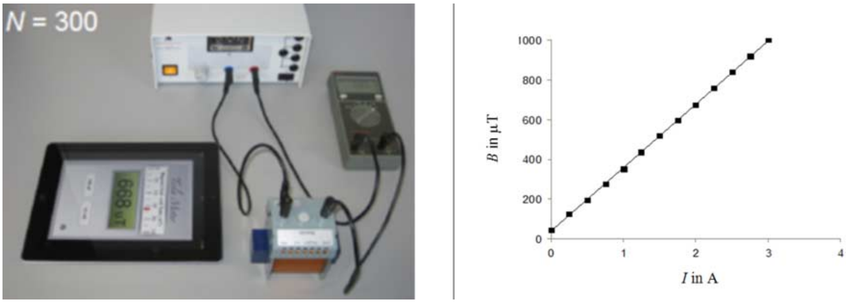

Figure 3. Magnetism experiment in real-life setting with a tablet PC.

3.3. Augmented Pocket-Lab Environment: Enrich the Real World Experiences by Conceptual Augmentation

In this learning space it becomes more important that the experimental procedure is as simple as possible for students because of their built up basic competences to allow them engaging in an explorative process in which hypotheses emerge, lead to new measurements, and observations are eventually rejected, modified, or accepted with different students following their own paths and ideas. Following the magnetism example students analyse the relationship between the magnetic flux B of a coil and the number of coil-loops N. Again the mobile device must be positioned with its magnetic field sensor in front of the coil's longitudinal axis and set up the experiment as presented in Figure 3 (left side). Second, for studying the B-N-relationship, they start a relevant app (e.g. Tesla Field Meter for iOS or AndroSensor for Android) and measure B successively for coils with different N. The data is then plotted automatically in the B-N-diagram and with the camera of the mobile device focus on the coil its magnetic flux lines (incl. vectors) are visualized by AR by object recognition. So this learning space presents learning proposals which are augmented by relevant representations to improve especially conceptual learning.

3.4. Exploring Physics Theory in the Virtual World

Virtual spaces, such as virtual worlds and immersive virtual realities, allow more advanced and interactive forms of online and digital learning and experimenting. They support interactive internet-accessible physics experiments and can be used to visualize different phenomena, which are in real life too expensive, too dangerous, or invisible. We define two major versions of virtual environments: (a) single-user environments, accessible for only one user, and (b) multi-user environments, which support the access to the virtual environment for several users in form of avatars and support communication and collaboration. Multi-user environments additionally enable collaborative remote learning scenarios. With the introduction of innovative and affordable VR devices (e.g. Oculus Rift or Google Cardboard) for the living room, also well-designed immersive

VR-experiences become more and more relevant for personal distant learning and training scenarios. Figure 4 illustrates a collaborative virtual world setup, which is designed for small student groups to learn the physics of Faraday's Law together. While they are working together on different experiments and are interacting with the three-dimensional visualizations, they can communicate synchronously with VoIP [21]. The smart assistant can be included in the virtual experiments, tracking what learners are doing.

Figure 4. Magnetism experiment and theory in the virtual reality.

4. Smart Assistant

4.1. Psycho-Pedagogical Approach

The overall psycho-pedagogical approach underpinning the smart assistant consists of a combination of different pedagogical paradigms and learning theories. This blend allows for aligning the smart learning environment with formal and informal settings. Furthermore, they provide the basis for the learning support based on technical methods.

The experience-based learning model developed by Kolb [14] is a learner-centric model that regards learning as the process where knowledge is created through the transformation of experience. This model suggests that experiments stimulate the conceptualisation and reflection of new domain knowledge and thus deeper understanding is achieved. In order to achieve a systematic approach for knowledge attainment, the psychological-mathematical framework Competence-based Knowledge Space Theory [11] is employed that provides an approach for representing skills and knowledge of both the physics subject domain and the learner. This framwork also has available methods for adaptive guidance and testing, in order to personalise the learning experience.

On a meta-level self-regulated learning describes a learner-centric approach, where the learner takes over control of the own learning process including goal setting, planning, self-monitoring, self-reflection, and self-evaluation [25]. While the experience-based learning model rather targets the acquisition of domain (physics) skills, self-regulated learning targets the application of meta-cognitive skills to control the learning process. Another way to raise the students' motivation and engagement with the learning material is to enrich learning with elements and strategies originated from game design. This process is called gamification [5] and supports the learner to interact with the system in a motivating and playful way. Different studies show the effectiveness of gamification strategies in learning contexts (e.g. [13] [22]).

4.2. Adaptive Guidance Through Smart Assistant and Gamification

The central component that manages the personal guidance is the smart assistant. This component is installed on all the mobile devices and in the virtual reality. It tracks the activities of the learner, the visited concepts, and the performed experiments in all modalities and sends the respective data to the back-end services. This data is used to derive a user profile in terms of visited resources, related competences, and potential learning problems. Based on this information, the smart assistant can provide personalised recommendations. For example, it can recommend which topic should be learned, which material or experiment should be performed, or which modality (augmented book, mobile device, virtual reality) should be used. The smart assistant should utilise a narrative-based approach [4] to ensure the concepts connect with experiences the learner has had. In this way the smart assistant connects the modalities and enables a meaningful traversing through them. Furthermore, it implements the pedagogical concepts described above. For example, it can be designed to recommend physics concepts in a meaningful sequence based on their prerequisite structure.

Gamification in our approach is used as constant companion of the learner in all the different smart learning environments and technologies. It is used as a strategy to enhance the learning experience with engaging and feedback elements. These feedback elements include for example points, progress-bars, or badges for special achievements. As a constant companion, the entire progress and the achievements are not only visible inside the current smart technology, but also in a separate cross-platform, which can be also used to share achievements with other learners for social engagement.

5. Conclusion and Future Work

This position paper presented an approach that targets the advancement of physics learning by taking into account new developments regarding mobile devices and their sensors, augmented reality, and virtual reality. Learners will be empowered to do physics experiments in real world settings and in virtual reality environments, thus applying conceptual knowledge learned with augmented reality technologies. Personalisation approaches and related services in the background support the learners by considering their individual preferences and needed amount of guidance.

The overall approach is seen as basis and direction for future research and development in these areas. It relates individual work on physics experiments with mobile devices, augmented reality, and virtual reality to a broader concept of physics learning. Thus it enables the continuous work towards the overall approach. Though the achievement of this overall goal would require a lot of efforts, the development of individual parts are more realistic for the near future. For example, doing experiments with mobile devices and using augmented reality for further help are doable in rather short time.

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Using Serious Games in Higher Education: Reclaiming the Learning Time

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Abstract. Today"s technology provides learners with full control of when, where and how they will access the learning material. Although the advantages are apparent , there are also some “side-effects”. One of them is that the “learning time” is not explicitly defined anymore. It is the design of the learning application that should consider for this, reclaim the learning time and create the necessary conditions for the “learning momentum”. The aim of this paper is to present a serious game that has been created for Law students at the University of Westminster, London, and to discuss the cognitive processes it activates. Serious games aim to teach students, using techniques from the game industry. Gamified elements are used alongside educational theories. The game presented here is a simulation of a tutorial that teaches the “Law of murder”. Students are presented with a case, they are asked to apply the law and decide if this is a murder or not. During the game the main principle of “learning by doing” is applied. One of the objectives of the game is to make students to focus on the topic and make the best use of the “learning momentum”.

Keywords. Serious Games, Learning Time, Cognitive Processes, Aspects of Serious Games

1. Technology in Higher Education: the “learning momentum”

Technology is used in education for quite long time; as a result we have enough evidence to decide about the advantages it offers to learners. Researchers agree about the educational benefits of technology, however they emphasize that there are a number of factors related with these benefits. Whatever the technology is, (from cloud computing and learning analytics to games and podcasts [2], [4], [5]) researchers seem to agree that the design of the educational application and the way it will be used are of enormous importance.[3]

Technology changes not only the way we access knowledge – it also changes the way we understand it. Especially the use of hypertext puts learners in the driving seat in relation to what information they access and how they will use it. Learners are in full control of when, where and how they will access the learning material – the advantages are apparent. On the other hand, having access to teaching material at any time and from anywhere directly affects the way the “class” or “tutorial time” is to be used. Huge amount of information and teaching material can be saved in order to be used, *“later”*.

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In Higher Education a "side-effect" of this advantage is that the perception of "class / tutorial time" changes. Traditionally "tutorial time" was considered as "time to learn". Today, students often do not make the best use of the tutorial time because they know that they can store the information. On one hand this is an enormous advantage because we achieve "any-time" "any-place" learning but on the other hand students tend to do less effort in the class. They are more keen to store information than to understand it. Even in cases where students have to produce something (e.g. create a diagram with specific data), they often prefer to take a picture of it with their mobile phones or tablets instead of recreating it from scratch or just copy it. The sense of safety – that they will be able to revisit the information at any time – reduces their attention and effort during tutorial time. As a result "learning" tends to be postponed for "later".

Storing information safely, often makes students to lose the "learning momentum" – they do not have the feeling that this is the time to concentrate, to understand, to learn. The term "momentum" has been used in Psychology (especially sports psychology) and Physics. There are several definitions of "momentum" [1]; it has been defined as the "perception that the actor is progressing toward his/her goal. Such a perception of progression toward the goal is associated with heightened levels of motivation and enhanced perceptions of control, confidence, optimism, energy and synchronism" ([9] p. 94) as well as a "positive or negative change in cognition, physiology, affect, and behavior caused by a precipitating event or series of events that will result in a shift in performance" ([8] p. 51). Most definitions of "momentum" seem to agree that is related to cognition and it results in changes in performance.

In this paper we define the "learning momentum" as the specific time or period in which learners intensify their cognitive skills in order to achieve their learning goals. During those times learners have to heighten their attention and motivation. The sense that almost everything can be postponed (because it is safely stored) can be considered as an obstacle in the effort to achieve the "learning momentum". The challenge is to use technology in order to achieve the "momentum" and "reclaim the learning time" – in other words, in order to make students focus on the learning material within limited time and maximize the use of their cognitive skills without compromising the advantages of "any-time, any-place" learning.

2. Serious Games @ Westminster: "The Law of Murder"

"Serious games" are simulations of real-world events or processes designed for the purpose of teaching and training. Their aim is to enhance understanding of key concepts, along with the development of cognitive skills. As they are more likely to capture the imagination of students than other more traditional forms of classroom teaching, they have been characterised as "valuable pedagogic mediums" [7].

Here we will present and discuss the design of a game we developed at the University of Westminster, for the needs of the second year module "Criminal Law". "Law" is a discipline where "language" plays a major role. Lecturers in Law should *"explain"* more than *"show"* (as it happens in other disciplines such as "Programming"). As a result the design of interactive material that is not boring or trivial is a challenging task.

The topic of the game is "The Law of Murder" and it is a simulation of the tutorial used by the Lecturer. The "story" is about two friends: Alf and Bob. After an argument

Alf makes and action that results in Bob"s death. Students have to decide if this is a murder or an accident. In order to do that, they have to study and analyze the "law of murder" and apply it to the specific facts. The IRAC framework (**I**ssue-**R**ule-**A**nalysis-**C**onclusion) that is used in the analysis of legal cases was followed. The game is a journey during which students have to go through 6 steps: factual analysis; understanding the law of murder; apply the law of murder on facts and identify issues; analyse causation; analyse intention and reach the final verdict (see Figure 1). In each step there are several game activities that try to keep students" interest alive and involve them with the case.

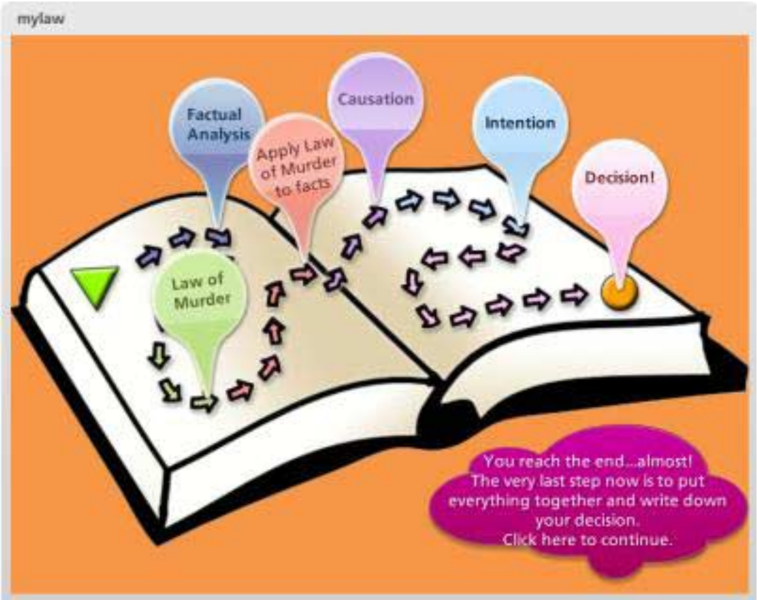

Figure 1. The "Law of Murder" – pathway

At the beginning, the story is presented as a "comic". Students have to identify evidence in the pictures and in the text that accompanies the pictures as well as in the dialogues between the two friends. Several activities with gamified elements were designed and implemented: multiple choice questions; give your own answer; complete the triangle, knowledge game. Simulation of elements of well known TV games (such as "50/50 help" and "Use the dictionary") has been used. Behind the "entertaining" character of this application there are several pedagogical objectives: active involvement of students; understanding; reading and writing skills.

One of the main challenges in this game was to create the "learning momentum". Based on the definition we provide before, we tried to make students to focus on the learning material within limited time and maximize the use of their cognitive skills.

3. Reclaiming the "learning time"

In order to create our game we simulated the steps that are usually taken during a tutorial. "Timed activities" and "active participation" were used.

3.1. Timed activities

Students are given the first and the last in a series of events and they are asked to use their knowledge and imagination in order to fill the gap. They are given 1 minute to answer the question “What kind of questions would you ask in order to find out what happened between Alf and Bob?” (see Figure 2). They are provided with space where they can write any question they like. Student answers are saved on a variable and are used in the next activity.

The main purpose of this activity is to make students work on the facts. They have to understand how the story started and how it ended. They are given very limited time in order to complete the answer. It is this limited time that creates the “momentum”. Players do not have as much time as they want or several chances to complete the activity. If the activity is not completed within the given time then they lose marks and they might not be eligible to continue to the next step.

The decision about the time that is given to students to complete this exercise was an important one. The purpose was to keep the attention of players focused on the story and make them participate actively. Most teachers and psychologists agree that the ability to focus attention on a task is crucial when we try to achieve a specific goal. Although the importance of attention is undeniable the “attention span” (the amount of concentrated time one can spend on a task without becoming distracted) causes discussions among psychologists and it depends on how we define “attention”. The short-term response to a stimulus (“transient attention”) could be between 1 to 10 seconds [6]. The long-term attention could be up to 8 minutes. We decided to keep the time tight and we gave only one minute to this activity.

Figure 2. Timed Activity (1)

After the one minute expires, students continue to the next activity where they are presented with sample correct answers and their own answers; they are given another minute to compare them (see Figure 3). During this time they have to read and understand the correct answers and to "assess" themselves – in other words to find out if and how many of the correct answers they have managed to identify. The first timed activity requires from students to concentrate and compose their own answer and then it feeds the next timed activity where students are asked to compare their answer with possible correct answers. Although there is no personalized feedback at this stage, the way that this part is designed is a direct simulation of what happens during the tutorial time: students have to understand the correct answer and partially peer observe their work.

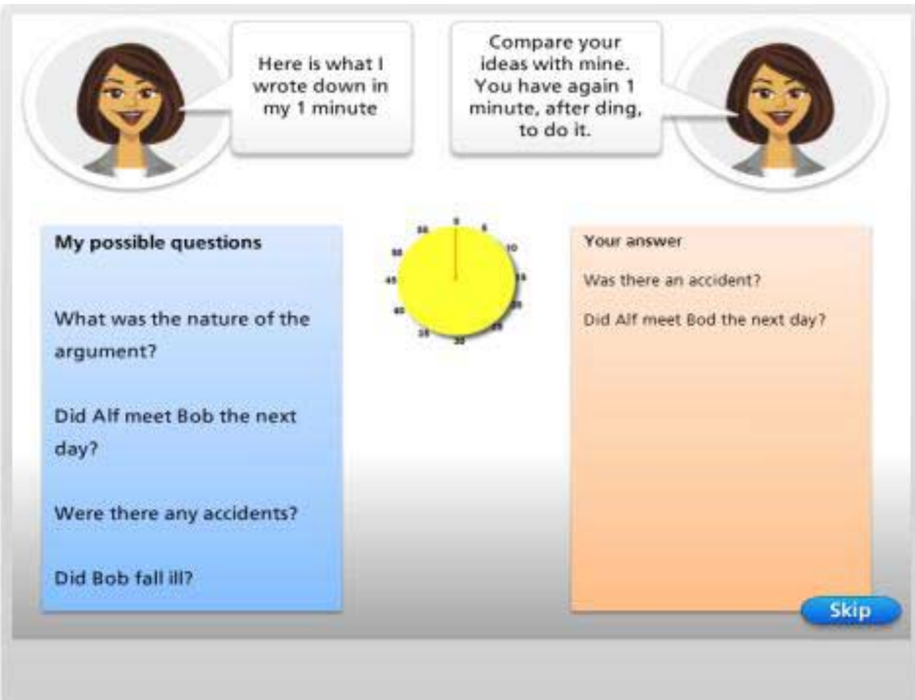

Figure 3. Timed Activity (2)

3.2. The "back" button

Another way to intensify learners" attention is the lack of "back" button. Deliberately the application does not provide any "back" button. Feedback – wherever it is needed – is provided on the spot and students are not given the chance to go back and do an activity again. The reason behind this design decision is not only because usually games do not have "back" buttons. Not having a "back button" in a learning application with gamified elements is done in order to achieve the maximum concentration. It is the effort to reclaim the "learning time" – the time that students have to focus and make the most out of it.

4. Implementation, evaluation and further work

The implementation has been done with “Articulate Storyline 2”. Storyline is an e-learning authoring platform. There are several reasons why we chose to use an e-learning authoring software instead of a game creating tool. Some of them are:

- easiness of use;
- great tools to build interactivity;
- developers can add web objects as well as their own code.

Furthermore, a “Storyline” project can be published in multiple formats so students can use the output on their i-Pads or Android devices as well as desktops and laptops. Published projects can be distributed via “virtual learning environments”, such as Blackboard and Moodle.

As the “game-tutorial” unfolds students have to complete several games where they gain points. The published version (HTML5) is connected with Google Documents. The results for each activity are saved in variables in a Google Form. Furthermore, all the actions of students are saved on variables; for example, we can see how many efforts students did before they provided the correct answer as well as what the previous efforts were. The game consists of 97 variables that are related with learning objectives. Variables 26-33 are related with the following question (see Figure 4) and provide information about the answers players tried before the correct one, if they used any “help” (“Use the dictionary” and / or “50/50”) as well as the points they gained from this questions and the total score at this stage of the game.

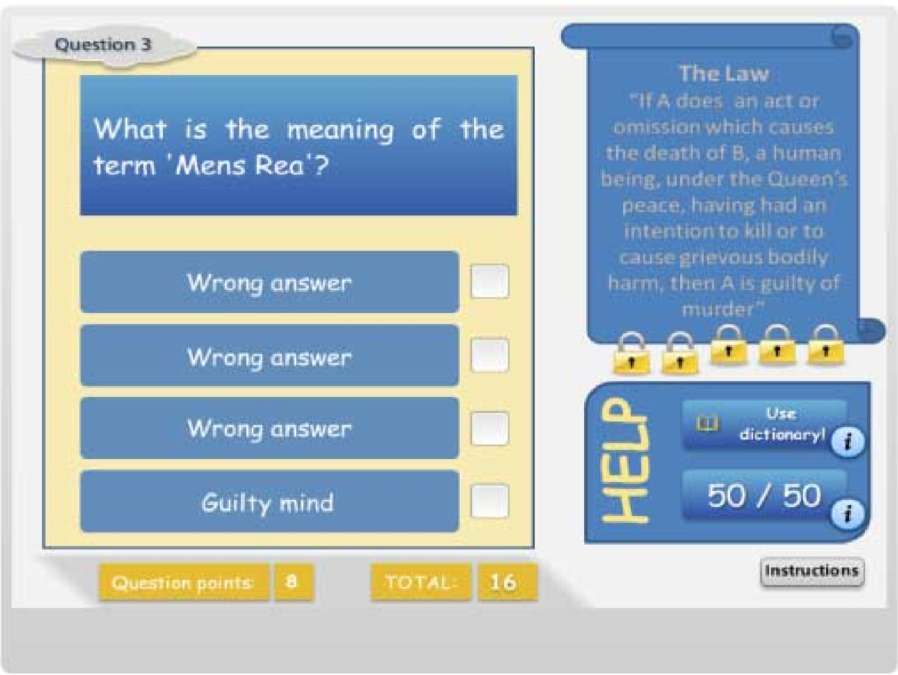

Figure 4. Question with help

Up to spring 2015, an initial expert evaluation has been completed. The game was evaluated with 4 lecturers at the Westminster School of Law. All of them were delighted with this and we received some very good comments. Among the feedback we received were questions in relation to the "back button". As explained before, the lack of "back button" was done on purpose.

The above described game was developed for the "Criminal Law" module, at the University of Westminster, that is attended by over 300 students. A proper testing has been designed for students and it is expected to take place during summer / autumn 2015.

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Evaluation of a dynamic role-playing platform for simulations based on Octalysis gamification framework

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Abstract. The use of serious games (SG) in education and their pedagogical benefit is being widely recognized. However, effective integration of SGs in education depends on addressing two big challenges: successful incorporation of motivation and engagement that can lead to learning; and high cost and specialised skills associated with customised development to achieve the required pedagogical results. This paper presents a SG platform that offers tools to educators to dynamically create three dimensional (3D) scenes and verbal and non-verbal interaction with fully embodied conversational agents (ECA) that can be used to simulate numerous educational scenarios. We then evaluate the effectiveness of the platform in terms of supporting the creation of motivating and engaging educational simulations based on the Octalysis gamification framework. The latter includes a number of game design elements that can be used as appropriate in the optimization of the experience in each phase of the player's journey. We conclude with directions of the further extension to our platform to address the aforementioned gamification framework, as well as directions for further development of the Octalysis framework.

Keywords. Gamification, framework, Octalysis, dynamic, role-playing platform, simulations, cognitive, learning

1. Introduction

A number of projects have investigated the use of SG in education and their pedagogical benefit is being widely recognized. The successful use of SG for learning is based on adopting gamified elements that support increased motivation and engagements which are usually considered prerequisites that lead to learning. The incorporation of game elements in non-game contexts is widely referred to as "gamification"[1][2]. Gamification is being increasingly recognized [5] as the process/technique of extracting motivating and engaging elements found in games and applying them to real-world productive or educational activities. Chou [2], recognizes this process as "Human-Focused Design" or else User-Centered Design (UCD), which appreciates user motives, cognitive and emotional states and therefore optimizes for their feelings, motivations, and engagement, as opposed to "Function-Focused Design",

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which is designed for pure efficiency. The term gamification has been adopted because it was the games industry that was the first to master UCD.

The successful incorporation of gamification particularly in educational context is challenging. Rickel [6], notes that stories with interesting characters have a powerful ability to engage and capture our attention and leave memorable impressions. Students, in interactive smart virtual environments (VEs) with interesting virtual characters, may experience the scene in a more interactive, engaging and immersive manner. Hence, the virtual experience can enhance their learning constructively by providing new educational capabilities [7]. A number of research projects have attempted to embody virtual characters with verbal and nonverbal communication and to evaluate their impact in computer-based learning environments [8][9]. Generally, ECAs allow richer learning experiences as the interaction is multimodal (e.g., gaze, facial expressions, head nods and gestures).

However, despite the increased number of systems featuring ECAs in various learning domains, current systems offer limited options to instructors to adapt the system to suite various scenarios within a single domain, not to mention to apply gamified elements that would aid the educational experience. Typically, these environments offer a level-builder that allows some degree of content adaptation. In particular, users can load a predefined 3D object in the builder and modify its appearance through a menu of choices. The main advantage of this approach is that the user can apply various props (e.g., hair, clothes, etc.) on the 3D mesh without modifying its basic attributes (e.g., animations, morphs, etc.). Creating fully instructor/lecturer-driven scenarios requires tools that allow the creation of custom-made 3D environments (including the appearance of the models and the content of the dialogue between the student and the ECA) and gamified features, like competition, time constrains, levels of difficulty, milestones, feedback etc. that fully reflect a given scenario.

Section 2, of this paper presents a SG platform architecture that allows the dynamic creation of 3D scenes, interaction with ECAs and setting up milestones and duration to simulate numerous educational scenarios, without requiring specialized technical or artistic skills. Section 3, we present a gamification framework, which includes a number of game design elements that can be used in the optimization of the experience of the player's/students journey. Section 4 evaluates the effectiveness of the aforementioned platform in terms of supporting the creation of motivating and engaging educational simulations based on the Octalysis gamification framework. The paper concludes with directions for further extension to the SG platform to address the Octalysis framework, as well as directions for further development of the framework.

2. Westminster Serious Games Platform (wmin SGP) System architecture

The wmin SGP has been designed following a UCD process, aiming to address specific educational requirements in Higher Education of academics of the Department of Politics and International Relations and Westminster Law School at the University of Westminster, who use simulations as teaching and learning tool. The wmin SGP is a 3D interactive system that allows multimodal interaction with ECAs (play mode) and dynamic creation of gamified scenarios and dialogues with the use of an intuitive graphical user interface (GUI) (edit mode) [12]. Thus, the wmin SGP promises to enable the creation of endless scenarios intended for a wide range of topics and student needs.

The Wmin SGP edit mode (see Figure 1) consists of five components:

1. *Scene Editor (SE),* which offers a matrix-style environment where instructors/learners can develop custom-made scenes with fully-functional ECAs.
2. *Natural Language components (NLC)*, which processes input text in plain English and generate relevant responses.
3. *The non-verbal behaviour generator (NVBG)*, a rule-based component that analyses an ECA response and proposes appropriate non-verbal behaviours (gestures, face expressions and gases) which is defined in its behavioural file.
4. *The Speech components (SC)*, a Text-to-Speech (TTS) component generates the ECA's speech and the timing needed to synchronize the speech with the non-verbal behaviours.
5. *The Dialogue Editor (DE)*, a tool designed to help instructors/learners create dialogues and select relevant non-verbal behaviours.

To build a role play simulation, instructors/learners must go through five steps:

1. Create the 3D scene and bring in Virtual Humans (VHs) – Instructors/learners can load an empty environmental template and VHs to create a scene that fully reflects the requirements of a given scenario. The GUI offers tools and guidance to assist the editing process (see Figure 1). Objects have a standard menu with various manipulation options (e.g., move up or down, rotate, etc.). A dummy character provides a visual indicator of the user's viewpoint of the scene.
2. Create a text based introduction to describe the game objectives.
3. Create Conversational Milestones – Conversational milestones are key-points in the dialogue that can be displayed to aid/direct the learners to elicit the required information via their interaction/communication with the VHs. It is also a means of feedback for the learners about their progress in achieving their goals.
4. Toggle simulation timer – Content authors can increase the level of challenge each scenario poses by adding a countdown timer. This means that learners have to play against time to meet the requirements of the scenario. The game ends once the allocated time has expired.
5. Create and assign dialogues to characters using a modified version of the virtual human builder (VHBuilder)– Instructors/learners define the verbal and non-verbal responses of the ECAs in the scene. Q&A pairs are entered in plain English and are linked to VHs and behavioural rules (animations, facial expressions) can be modified or created. The tool can access a number of predefined libraries of face, body and location animation (e.g., walking, running, etc.).

Once a simulation is completed it is being added in a database/a library of simulations that can be accessed from a drop down menu. The users can then play/run the simulation and interact in the VE and with the VHs in order to: for learners, to achieve the objectives of the simulation; or for instructors, to assess the completeness of a simulation that learners might have created.

The wmin SG platform has been developed using Unity 3D game platform [10] coupled with the ICT Virtual Human toolkit [11]. The latter is an open-source collection of modules, tools and libraries that facilitates the creation of ECAs. Its main render is Unity3D that makes contents created with the toolkit accessible through the WWW through Unity's Web player.

Figure 1. A screenshot of the edit mode of the wmin SGP that provides guidance to the user to edit the scene and use the available editing tools.

Empowering lecturer/instructors to create custom-made scenarios and iteratively improve them with the help of the students should provide a more comprehensive coverage of the intended learning outcomes than when the scenario is crafted by the developer alone. The Octalysis framework which is presented in (Section 3) offers the potential to reviews the gamified features supported by wmin SGP that contribute to the creation of engaging and motivating educational experiences.

3. Octalysis gamification framework

Octalysis is a framework that organizes systematically a list of gamified elements or cognitive drives (see Figure 2) that can be used in UCD to make an application engaging and motivating [2]. The framework suggests that almost every game is "fun" because it appeals to certain core drives within human that motivate players towards certain activities. The Octalysis framework organizes those motivating factors into the following 8 core drives which is based on an octagon shape hence its name:

1. *epic meaning and calling* is the need to participate in something bigger than just yourself;

2. *development and accomplishment* is about motivating people because they are feeling that they are improving, they are leveling up and achieving mastery;

3. *empowerment of creativity and feedback* is the core drive that motivates people to incorporate their creativity, try different combinations and strategies, seek feedback and adjust;

4. *ownership and possession* is the primary core drive that motivates people to accumulate possessions, improve it, protect it and get more;

5. *social influence and relatedness* refers to the activities motivated by the influence of other people (e.g., by what other people do or think);

6. *scarcity and impatience* is what motivates people to want something they cannot have (e.g., because it is not immediately or easily obtainable);

7. *unpredictability and curiosity* is willingness to discover the unknown outcome and involve chance;

8. *loss and avoidance* refers to the motivating factors that help people avoid situations they do not want happening (e.g., to die in a game).

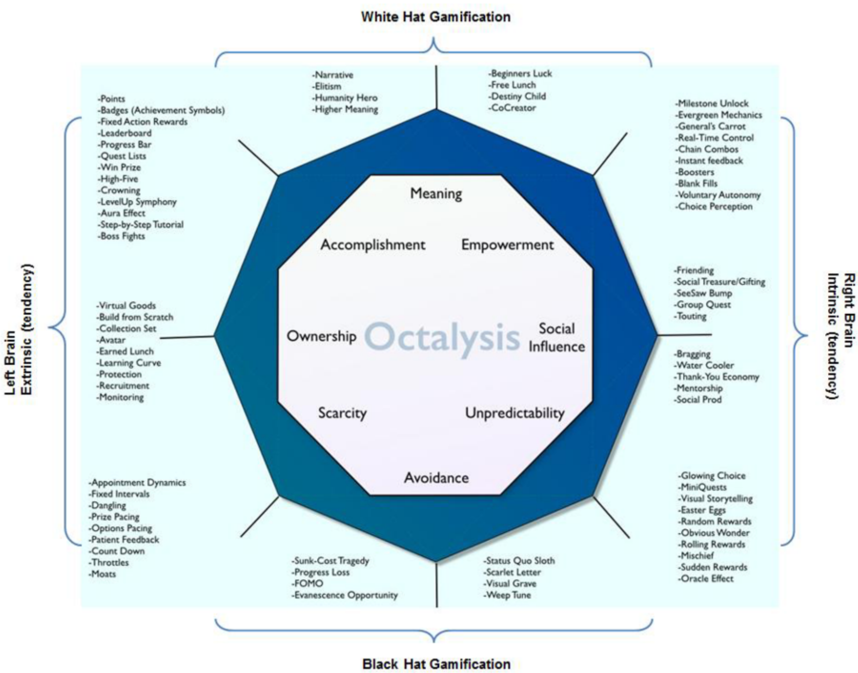

Figure 2. The Octalysis Gamification Framework [2]

Within Octalysis, the core drives on the right (see Figure 2) are considered Right Brain core drive and are related to creativity, self-expression, and social aspects. The Left Brain core drives have a tendency of being more based on Extrinsic Motivation which means that the motivation is to obtain something, whether it is a goal, a good, or anything you cannot obtain. The core drives on the left (see Figure 2) are considered Left Brain core drives and are associated to logic, calculations and ownership. The Right Brain core drives have a tendency of being based on Intrinsic Motivations which means that the motivation is that the activity itself is rewarding on its own and you do not need a goal or a reward.

Some extra dimension to the framework is that the top core drives in the octagon are considered very positive motivations – white hat, while the bottom core drives are considered more negative motivations – black hat. The white hat gamification involves motives that engage the user/player in activities that allow expressing creativity, and achievement through skill mastery, which encourages a higher sense of meaning, confidence and empowerment. The black hat gamification on the other hand involves motives that drive active engagement based on uncertainty and the fear of losing something. Such type of interaction nurtures bad emotions. To achieve good gamification all 8 core drives should be considered on a positive and productive activity so that everyone ends up happier and healthier.

The following section reviews the gamified features that are supported by wmin SGP using Octalysis framework. This analysis provides an indication of how satisfactory the platform supports tools to allow the creation of engaging and motivating educational experiences.

4. Evaluation of the wmin SGP based on the Octalysis framework Core Drives

Creating an experience incorporating the right game mechanics and game design techniques to engage and motivate people to achieve their learning objectives requires deep analysis, reasoning, testing and adjusting. This section reports preliminary expert evaluation result of wmin SGP against Octalysis core drives (see section 3) based on four expert evaluators using the Octalysis Tool. This is an online tool that allows evaluators to assess a product/process against the Octalysis core drives using a scale of one to ten, where 10 is “best” and based on the overall scoring it reports on how well those have been incorporated in the system/process. The scope of this evaluation was to review the wmin SGP play mode features and editing tools (see section 2) that are used to create bespoke game simulations that fulfill specific educational requirements.

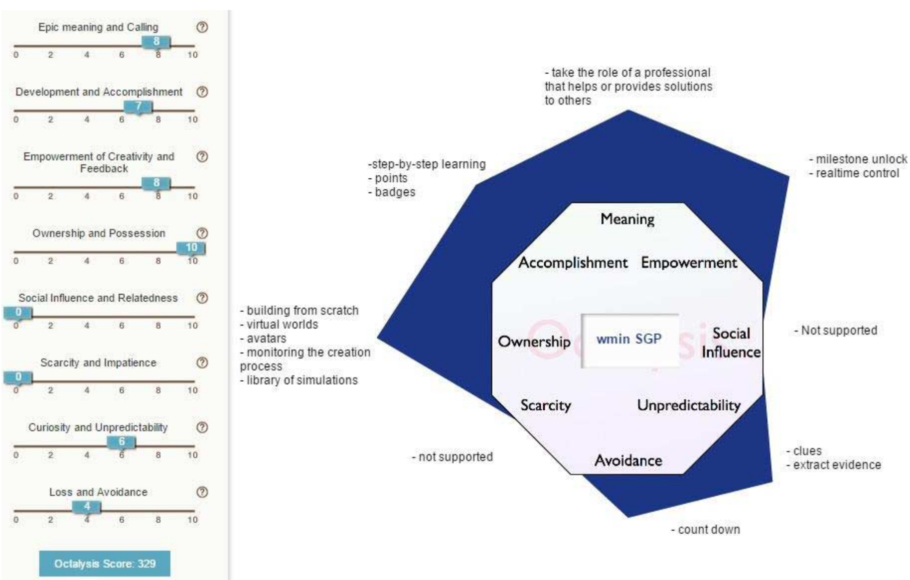

Figure 3. Average of the score provided by expert evaluators to wmin SG using the Octalysis Tool.

The expert evaluators spend enough time getting familiar with the use of the wmin SGP. Then they followed an explicit list of expected user actions to create two game simulations one for politics and one for law, and they have been asked to provide a score for each of the Octalysis core drives for wmin SGP tools and a short justification for their score. Below we provide a summary of the evaluators reasoning of their review, while figure 3, presents the average rating for each core drive accompanied by a graph that demonstrates the balance between them.

Epic meaning and calling – wmin SGP is designed for the creation of simulations that support learners to practice the professional role for which they are being trained. For example they may take the role of a lawyer, a counselor who intends to defend a person in need, or help their client respectively, or the political leader who is involved in influencing public policy and decision making. The simulations engage the learners in a **narrative** that involves **elicitation** of information to apply the law, extract evidence based on which to defend a client, provide the best advice to their client, negotiate or take political decisions. Thus, the platform is considered as a tool that strongly supports meaning.

Development and accomplishment – wmin SGP provides an environment that supports a **step-by-step** process that helps the learners achieve a set of **milestones** linked to learning goals. Milestones could be associated with **points** or **badges** to be won that could reveal their level of achievement.

Empowerment of creativity and feedback – is supported in terms of **unlocking milestones** and controlling the narrative and the way that the activity advances in **real-time**. There are various directions that empowerment could be enhanced that would be very suitable to the abovementioned learning activities. By providing **instant feedback** and awarding learners with boosters for example.

Ownership and possession – is strongly supported by the wmin SGP, as the whole concept of the platform is based on allows **building from scratch** bespoke simulations, with custom made **virtual worlds**, **avatars** and narratives. The five steps process of building simulations presented in (section 2) assists **monitoring** the process of creating the simulations. The system allows the creation of a **library/collection set** of simulations that could be linked when the learners progress through their learning journey.

Social influence and relatedness and *scarcity and impatience* are not supported by the platform. Social influence and voting are interesting concepts with potentially strong benefit to learning to be exploited.

Unpredictability and curiosity – is supported as far as **visual storytelling** is concerned, gradually discovering clues and collecting information that aids the creation of the broader images of a simulation based on which decision making can occur.

Loss and avoidance – is supported in terms of increasing the level of challenge each scenario poses by adding a **countdown timer**. The learners have to play against time to meet the requirements of the scenario. The game ends once the allocated time has expired. An interesting concept that could increase or sustain engagement would be to add a factor of negative marking, loosing points or boosters that have been gained, that could be linked to time that a task is completed or the learner to progress to the next level.

The Octalysis Tool average score for wmin SGP was 329 which demonstrates that the platform allows the creation of fairly balanced simulations in both White Hat and Black Hat core drives. In addition, it showed that there is a good balance between Left

Brain and Right Brain core drives, which means that there is a prospective to support a good equilibrium between Intrinsic and Extrinsic Motivation.

5. Conclusions and future directions

In this paper we presented the viability of wmin SGP to: dynamically create 3D scenes; and interaction with fully ECAs; simulate a number of hypothetical scenarios to support educational purposes. We analyzed the platform's gamified features using a small number of expert evaluators against Octalysis gamified framework and we encouraging review of a fairly balanced simulations that can lead to the creation of motivating and engaging experiences. The evaluation process indicated that future work should be focusing on improving or adding various game-like features to better assist educational purposes. For example linking milestones with time constraints for the completion of a task, offering a scoring system linked to the resolution of the simulation and linking this to the provision of educational support (like feedback and direction to relative readings/resources). Last, emphasis should be on improving the VHs' contextual awareness to be able to intervene when necessary to engage the users. Last extending the platform to support social influence, should be exploited. In addition, the Octalysis framework core drives need to be evaluated to assess how effectively learning is addressed.

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